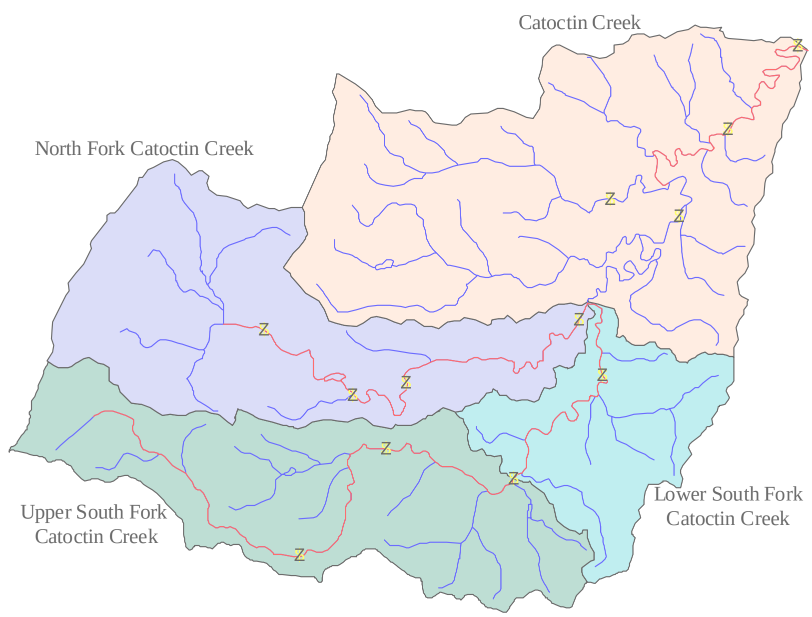
Fecal Coliform TMDL
(Total Maximum Daily Load)
Development for Catoctin Creek Impairments, Virginia



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Fecal Coliform Impairment

The South Fork Catoctin Creek, North Fork Catoctin Creek, and Catoctin Creek were placed on the Commonwealth of Virginia's 1998 Section 303(d) List of Impaired Waters because of violations of the fecal coliform bacteria water quality standard. In addition, Virginia's 2002 Section 303(d) extended the impairment of the South Fork Catoctin Creek into its headwaters. This listing was referenced in this document as the Upper South Fork Catoctin Creek. These TMDLs focus on fecal coliform impairments. Based on exceedances of this standard recorded at Virginia Department of Environmental Quality (VADEQ) monitoring stations, the stream does not support primary contact recreation (e.g. swimming, wading, and fishing). The applicable state standard specifies that the number of fecal coliform bacteria shall not exceed a maximum allowable level of 1,000 colony forming units (cfu) per 100 milliliters (ml) (Virginia Water Quality Standard 9 VAC 25-260-170). Alternatively, if data is available, the geometric mean of two or more observations taken in a thirty-day period should not exceed 200 cfu/100 ml. A review of available monitoring data for the study area indicated that fecal coliform bacteria were consistently elevated above the 1,000 cfu/100 ml standard. In TMDL development, the geometric mean standard of 200 cfu/100 ml was used, since continuous simulated data were available.

Sources of Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source contributions. Nonpoint sources include wildlife; grazing livestock; land application of manure; land application of biosolids; urban/suburban runoff; failed, malfunctioning, and operational septic systems, and uncontrolled discharges (straight pipes, dairy parlor waste, etc.). To account for un-quantifiable loads from known wildlife species, a background load was applied to all land segments equal to 10% of the total wildlife load quantified. Permitted point discharges in the Catoctin Creek drainage area include; Hamiltion Sewage Treatment Plant, Purcellville Water Treatment Plant, Waterford Sewage Treatment Plant, and one private residence. Of these, Hamiltion Sewage

Treatment Plant, Waterford Sewage Treatment Plant, and the private residence are expected to contain measurable amounts of fecal coliform.

Water Quality Modeling

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and perform TMDL allocations. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model.

Fifteen-minute flows from the US Geological Survey gage (#01638480) located at Route 663 in Taylorstown were used for direct calibration. The representative hydrologic period used for calibration ran from October 1, 1990 through September 30, 1995. The model was validated using 15-minute flows recorded at the same gaging station from October 1, 1995 through September 30, 1999. The time periods covered by calibration and validation represent a broad range of hydrologic and climatic conditions and is representative of the long term precipitation and discharge record. For purposes of modeling watershed inputs to in-stream water quality, the Catoctin Creek drainage area was divided into sixteen subwatersheds. The model was calibrated for water quality predictions using data collected at VADEQ monitoring stations between January 1993 and December 1997, and validated using data collected between January 1998 and December 2000. All allocation model runs were conducted using precipitation data from January 1993 through December 1997.

Existing Loadings and Water Quality Conditions

Wildlife populations and ranges; biosolids application rates and practices; rate of failure, location, and number of septic systems; domestic pet populations; numbers of cattle and other livestock; and information on livestock and manure management practices for the Catoctin Creek watershed were used to calculate fecal coliform loadings from land-based nonpoint sources in the watershed. The estimated fecal coliform production and accumulation rates due to these sources were calculated for the watershed and incorporated into the model. To accommodate the structure of the model, calculation of the fecal coliform accumulation and source contributions on a monthly basis accounted for seasonal variation in watershed activities such as wildlife feeding patterns and land application of manure. Also, represented in the model were direct nonpoint sources of properly functioning septic systems located within 50 feet of a stream, uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock.

Contributions from all of these sources were represented in the model to establish existing conditions for the watershed over a representative hydrologic period (1993-1997). Under existing conditions (2001), the HSPF model provided a comparable match to the VADEQ monitoring data, with output from the model indicating violations of both the instantaneous and geometric mean standards throughout the watershed.

Load Allocation Scenarios

The next step in the TMDL process was to determine how to proceed from existing watershed conditions to reduce the various source loads to levels that would result in attainment of the water quality standards. Because Virginia's fecal coliform standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the 200 cfu/100 ml geometric mean standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Modeling of these scenarios provided predictions of whether the reductions would achieve the target of 0% exceedance. Periods of low flow were critical in terms of water quality.

The set of scenarios explored pointed to the importance of reducing direct deposition loadings to the stream. The final load allocation scenarios required a 100% reduction in uncontrolled discharges and a 100% reduction in direct deposition to the stream by livestock for each of the four impairments.

A 91% reduction in direct deposition by wildlife was required in the Upper South Fork Catoctin Creek impairment. A 25% reduction in direct deposition by wildlife was required in the Lower South Fork Catoctin Creek impairment. A 93% reduction in direct deposition by wildlife was required in the North Fork Catcotin Creek impairment, and an

85% reduction in direct deposition by wildlife was required in the Catoctin Creek impairment.

Margin of Safety

In order to account for uncertainty in modeled output, a margin of safety (MOS) was incorporated into the TMDL development process. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. The purpose of the MOS is to avoid an overall bias toward load allocations that are too large for meeting the water quality target. An explicit MOS equal to 5% of the targeted geometric mean concentration of 200 cfu/100 ml was used in the development of this TMDL. As a result, allocations were made based on a modeled 30-day geometric mean not exceeding 190 cfu/100 ml.

Recommendations for TMDL Implementation

The goal of this TMDL was to develop an allocation plan that can be met during the implementation phase. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act states in section 62.1-44.19.7 that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters".

The TMDL developed for the Catoctin Creek impairments provides allocation scenarios that will be a starting point for developing implementation strategies. Modeling shows that periods of low flow are the most critical for water quality. This result points out the need to reduce direct deposition of fecal coliform bacteria to the stream. Additional monitoring aimed at targeting these reductions is critical to implementation development. Bacterial source tracking to identify more localized sources of contamination and an improved inventory of wildlife in the impairment area will contribute greatly to the implementation effort. Once established, continued monitoring will aid in tracking success toward meeting water quality milestones.

A staged implementation plan is essential to the process of restoring water quality. The goal of the first phase is to foster local support for the implementation plan and to reduce the violations of the instantaneous standard to no more than 10%. The model scenario developed for the first stage included a 100% reduction in uncontrolled discharges, and an 80% reduction in direct deposition to the stream by livestock. A phased implementation plan is necessarily an iterative process. There is a measure of uncertainty associated with the final allocation development process. Continued monitoring can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the Section 303(d) list.

Also critical to the implementation process is public participation. Permitted point sources provide a limited contribution to the overall water quality problem. Nonpoint direct deposition to streams is the critical factor in addressing the problem. These sources cannot be addressed without public understanding of and support for the implementation process. Stakeholder input will be critical from the onset of the implementation process in order to develop an implementation plan that is truly implementable.

Public Participation

During development of the TMDL for the Catoctin Creek, public involvement was encouraged through three meetings. A basic description of the TMDL process and the agencies involved was presented at the first public meeting. The second public meeting was held to discuss the source assessment input, bacterial source tracking, and model calibration data. The final model simulations and the TMDL load allocations were presented during the final public meeting. Public understanding of and involvement in the TMDL process was encouraged. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios developed.

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1. INTRODUCTION

1.1 Background

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (EPA 1991)

Portions of Catoctin Creek, North Fork Catoctin Creek, and South Fork Catoctin Creek were listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1998) due to violations of the State's water quality standard for fecal coliform at three monitoring stations. Out of 18 samples collected during the 1998 assessment period on the North Fork Catoctin Creek at the Route 681 bridge (river mile 0.42), 7 violated the water quality standard. During the subsequent 2000 assessment period, 6 of 19 samples violated the water quality standard. Out of 20 samples collected during the 1998 assessment period on the South Fork Catoctin Creek at the Route 698 bridge (river mile 1.66), 7 violated the water quality standard. During the subsequent 2000 assessment period, 6 of 20 samples violated the water quality standard. Out of 48 samples collected during the 1998 assessment period on Catoctin Creek at the Route 663 bridge (river mile 4.57), 9 violated the water quality standard. During the subsequent 2000 assessment period, 8 of 49 samples violated the water quality standard.

Catoctin Creek is located in Loudoun County and is part of the Potomac River Basin. The segment of the North Fork Catoctin Creek from the confluence of the North Fork Catoctin Creek with Catoctin Creek to a point 10.53 miles upstream is impaired. The impaired segment begins approximately 0.83 river miles upstream from the Route 719 bridge near Hillsboro. The segment of the South Fork Catoctin Creek from the confluence of the South Fork Catoctin Creek with Catoctin Creek to a point 6.01 miles upstream is impaired. Preliminary results from the 2002 Virginia Water Quality Assessment suggest that the entire length of the South Fork Catoctin Creek (17.26 miles) is impaired, and therefore the TMDL addresses all of the South Fork Catoctin Creek. The Upper South Fork Catoctin Creek impairment begins approximately 1.10 river miles upstream from the Route 761/Route 719 intersection, downstream to its confluence with the Lower South Fork Catoctin Creek. The Lower South Fork Catoctin Creek impaired segment begins approximately 0.55 river miles upstream from the Route 9 bridge downstream to its confluence with Catoctin Creek. The segment of Catoctin Creek from the confluence with Milltown Creek 7.40 miles downstream to its confluence with the Potomac River is impaired. The confluence of Milltown Creek to Catoctin Creek is approximately 1.20 river miles downstream from Route 673 bridge.

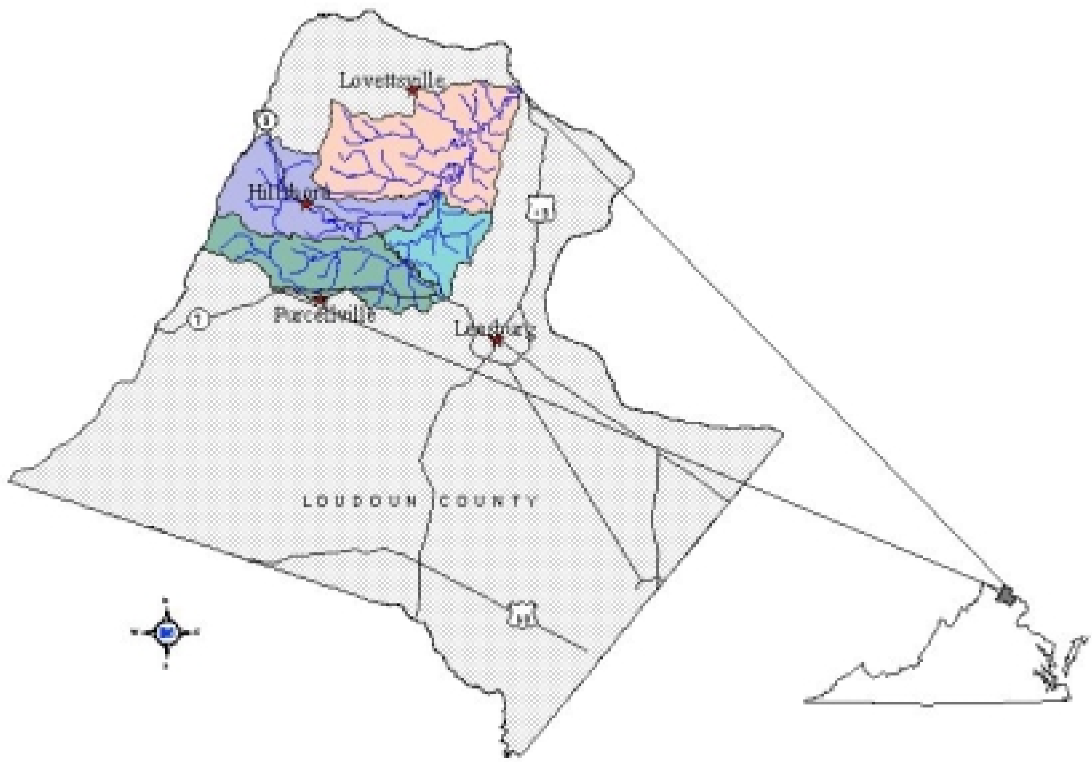

Figure 1.1 Location of the Catoctin Creek watershed.

The Upper South Fork Catoctin Creek, Lower South Fork Catoctin Creek, North Fork Catoctin Creek, and Catoctin Creek are part of the Catoctin Creek watershed, located in Loudoun County, Virginia, just north of Purcellville and approximately five miles to the northwest of Leesburg, Virginia (Figure 1.1). The Catoctin Creek watershed empties into the Potomac River, which empties into the Chesapeake Bay. The Catoctin Creek watershed is located within hydrologic unit (USGS No. 02070008) and Virginia hydrologic planning unit VAN-A02R. The total area of the Catoctin Creek watershed is approximately 59,090 acres, with agriculture and forest as the primary land uses (Figure 1.2, Table 1.1). Of this, the Upper South Fork Catoctin Creek watershed is approximately 14,117 acres comprised of forest (24.3%), agricultural (70.2%), urban (4.8%), and water (0.7%) land uses. Similarly, the 6,953 acres in the Lower South Fork Catoctin Creek watershed are distributed between forest (23.6%), agricultural (73.3%), urban (2.4%), and water (0.7%). The total area of the North Fork Catoctin Creek watershed is approximately 14,856 acres comprised of forest (41.0%), agricultural (57.6%), urban (0.6%) and water (0.8%). The Catoctin Creek watershed is approximately 23,164 acres comprised of forest (30.1%), agricultural (67.7%), urban (1.1%), and water (1.1%). The estimated population within the Catoctin Creek drainage area in 2001 was 9,757. Loudoun County ranked 2nd among Virginia counties, for the number of horses/ponies. (USDA NASS, 1997) Loudoun County ranks 44th, among Virginia counties, for the number of dairy cows, 14th for the number of all cattle and calves, 10th for beef cattle, and 37th for production of corn silage (VASS, 2000). For the period from 1930 to 2000, the Catoctin Creek watershed received average annual precipitation of approximately 41.6 inches, with 54% of the precipitation occurring during the growing season (May – October) (SERCC, 2001). Average annual snowfall is 21.9 inches with the highest snowfall occurring during January (SERCC, 2001). Average annual daily temperature is 56 ºF. The highest average daily temperature of 88.9 ºF occurs in July, while the lowest average daily temperature of 24.7 ºF occurs in January (SERCC, 2001).

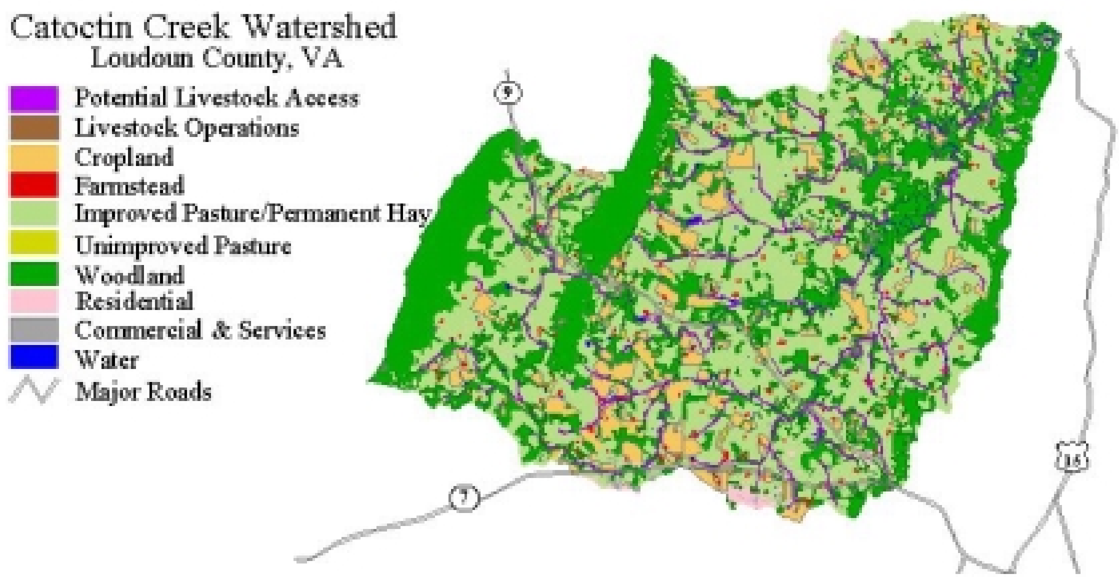

Figure 1.2 Land uses in the Catoctin Creek watershed.

Table 1.1 Spatial distribution of land use in the Catoctin Creek drainage area.

Land Use	Upper South Fork Catoctin Creek (ac)	Lower South Fork Catoctin Creek (ac)	North Fork Catoctin Creek (ac)	Catoctin Creek (ac)
Woodland	3,433	1,639	6,102	6,981
Water	100	48	114	248
Commercial & Services	200	37	2	6
Residential	473	129	83	247
Cropland	2,161	246	934	1,646
Livestock Operations	11	0	0	1
Farmstead	75	32	37	55
Unimproved Pasture	155	125	114	403
Improved Pasture	7,298	4,564	7,318	13,209
Potential Livestock. Access	213	132	152	370

1.2 Applicable Water Quality Standards

According to Virginia Water Quality Standard (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

Virginia Water Quality Standard 9 VAC 25-260-10 (Designation of uses.) states:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

♦

D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.

♦

G. The [State Water Quality Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentrations prevent the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;

♦

6. Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.

For a non-shellfish supporting waterbody to be in compliance with Virginia fecal coliform standard for contact recreational use, VADEQ specifies the following criteria (Virginia Water Quality Standard 9 VAC 25-260-170):

A. General requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.

If the waterbody exceeds either criterion more than 10% of the time, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion is applied to a particular datum or data set (Virginia Water Quality Standard 9 VAC 25-260-170). If the sampling frequency is one sample or less per 30 days, the instantaneous criterion is applied; for a higher sampling frequency, the geometric criterion is applied.

Sufficient fecal coliform bacteria standard violations were recorded at VADEQ water quality monitoring stations to indicate that the recreational use designations are not being supported (VADEQ, 1998). Most of the VADEQ ambient water quality monitoring is done on a monthly or quarterly basis. This sampling frequency does not provide the two or more samples within 30 days needed for use of the geometric mean part of the standard. Therefore, VADEQ used the 1,000 cfu/100 ml standard in the 1996, 1998, 2000, and 2002 Section 303(d) assessments of the fecal coliform bacteria monitoring data. A five-year time span was used for each assessment period.

For the Catoctin Creek watershed, the TMDLs are required to meet the geometric mean criterion since the computer simulation gives fecal coliform concentrations throughout the day, analogous to collecting samples throughout the day. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land-use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

1.3 Water Quality Standard Review

Two regulatory actions related to the fecal coliform water quality standard are currently under way in Virginia. The first rulemaking pertains to the indicator species used to measure bacteria pollution. The second rulemaking is an evaluation of the designated uses as part of the state’s triennial review of its water quality standards.

1.3.1 Indicator Species

USEPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. USEPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

1.3.2 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 and in Section 1.2 of this report. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream.” It is obvious that many streams within the state are not used for recreational purposes. In many cases, insufficient depth of the streams as well as wildlife impacts prevent the attainment of the primary water quality standard.

Additionally, the VADEQ and VADCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Virginia Department of Game and Inland Fisheries and analysis or “typing” of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl contribute to the elevated fecal bacteria counts in these streams.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, VA is considering re-designation of the swimming use for secondary contact in cases of: 1) natural contamination by wildlife, 2) small stream size, and 3) lack of accessibility to children, as well as due to widespread socio-economic impacts resulting from the cost of improving a stream to a "swimmable" status.

The re-designation of the current swimming use in a stream will require the completion of a Use Attainability Analysis (UAA). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

1.3.3 Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all of the sources of fecal coliform (other than wildlife), the stream will not attain standards. TMDL allocation reductions of this magnitude are not realistic and do not meet USEPA's guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife. **Virginia and USEPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** This is obviously an impractical action. While managing over-populations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. In such a case, after demonstrating that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs, the state may decide to re-designate the stream's use for secondary contact recreation or to adopt site specific criteria based on natural background levels of fecal coliforms. The state must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs through a so-called Use Attainability Analysis (UAA) as described above. All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and USEPA will be able to provide comment during this process.

This is obviously an impractical action. While managing over-populations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. In such a case, after demonstrating that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs, the state may decide to re-designate the stream's use for secondary contact recreation or to adopt site specific criteria based on natural background levels of fecal coliforms.

Based on the above, USEPA and Virginia have developed a TMDL strategy to address the wildlife issue. The first step in this strategy is to develop an interim reduction goal as discussed in Chapter 6. The pollutant reductions for the interim goal are applied only to controllable, anthropogenic sources identified in the TMDL, setting aside any control strategies for wildlife. During the first implementation phase, all controllable sources would be reduced to the maximum extent practicable. Following completion of the first phase, VADEQ would re-assess water quality in the stream to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the second phase because the water quality standard exceedances attributed to wildlife in the model are very small and infrequent and fall within the margin of error.

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

USEPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Catoctin Creek is protected during times when it is most vulnerable.

The South Fork Catoctin Creek and North Fork Catoctin Creek were initially placed on the Virginia 1996 Section 303(d) list of impaired waters based on monitoring performed. Catoctin Creek was initially placed on the Virginia 1998 Section 303(d) list of impaired waters. The Upper South Fork impairment will be listed on the Virginia 2002 Section 303(d) list of impaired waters. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these stream segments do not support the primary contact recreation use.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the Catoctin Creek TMDL, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations (Section 1.2 of this document). In order to remove a water body from a state’s list of impaired waters; the Clean Water Act requires compliance with that state's water quality standard. Since modeling provided simulated output of fecal coliform concentrations at 15-minute intervals, assessment of TMDLs was made using the geometric mean standard of 200 cfu/100 ml. Therefore, the in-stream fecal coliform target for this TMDL was a geometric mean not exceeding 200 cfu/100 ml.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards. Fecal coliform sources within the Catoctin Creek watershed are attributed to both point and nonpoint sources. Critical conditions for waters impacted by land-based nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include nonpoint sources that are not precipitation driven (e.g. fecal deposition to stream).

A graphical analysis of fecal coliform concentrations and discharge showed that there was no obvious critical flow level (Figure 2.1). That is, the analysis showed no obvious dominance of either nonpoint sources or point sources. High concentrations were recorded in all flow regimes. Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (Section 4.5). The resulting time period for calibration was October 1990 thru September 1995. For validation the time period selected was October 1995 thru September 1999.

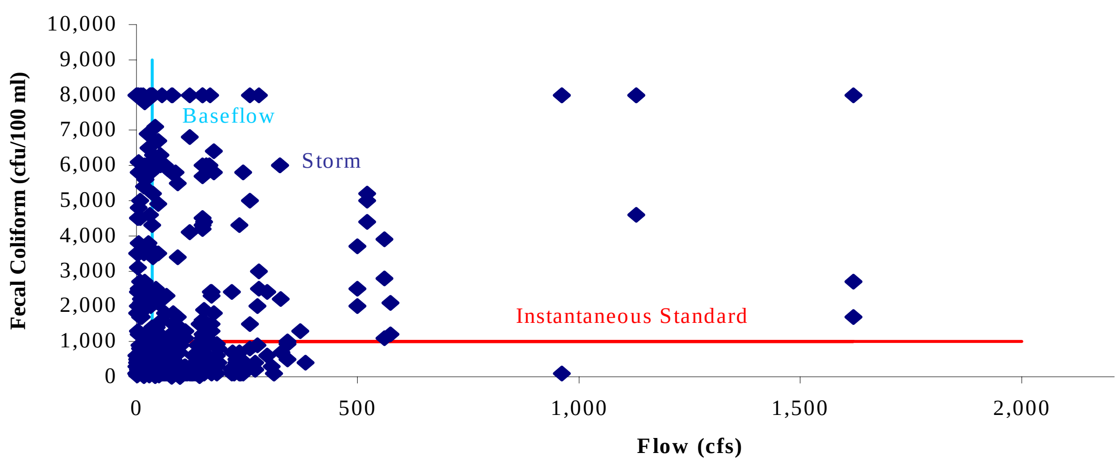

Figure 2.1 **Relationship between fecal coliform concentrations (VADEQ Station 1ACAX004.57) and discharge (USGS Gaging Station #01638480) in the Catoctin Creek watershed.**

2.2 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal coliform monitoring data throughout the Catoctin Creek watershed. Since water quality data was limited, an examination of all data available for the entire Catoctin Creek watershed were analyzed. Sources of data and pertinent results are discussed.

2.2.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- 18 VADEQ in-stream monitoring stations located in the Catoctin Creek watershed; and
- water quality monitoring conducted by MapTech, Inc. as part of the services contracted for this TMDL.

2.2.1.1 Water Quality Monitoring Conducted by VADEQ

Data from in-stream fecal coliform samples, collected by VADEQ, for Catoctin Creek are available from April 1973 through June 2001 (Figure 2.2) and are included in the analysis. Samples were taken for the expressed purpose of determining compliance with the state instantaneous standard limiting concentrations to less than 1,000 cfu/100 ml. Therefore, as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 ml or in excess of a specified cap (e.g. 8,000 or 24,000 cfu/100 ml, depending on the laboratory procedures employed for the sample) were not further analyzed to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 ml most likely represent concentrations below 100 cfu/100 ml, and reported concentrations of 8,000 or 24,000 cfu/100 ml most likely represent concentrations in excess of these values. Table 2.1 summarizes the fecal coliform samples collected at the in-stream monitoring stations.

Figure 2.2 Location of VADEQ water quality monitoring stations in the Catoctin Creek watershed.

Table 2.1 Summary of water quality sampling conducted by VADEQ for period April 1973 through June 2001.

Impairment and Station Number	Count (#)	Minimum (cfu/100 ml)	Maximum (cfu/100 ml)	Mean (cfu/100 ml)	Median (cfu/100 ml)	Violations[1] (%)
Catoctin Creek						
1ACAX000.19	51	90	6,000	925	100	16
1ACAX004.57	207	0	24,000	1,482	200	20
1CAX008.61	1	10	10	10	10	0
1AMIH001.98	1	100	100	100	100	0
North Fork Catoctin Creek						
1ANOC000.42	106	0	8,000	1,893	800	42
1ANOC004.38	53	100	6,300	1,023	300	25
1ANOC007.28	2	100	8,000	4,050	4,050	50
1ANOC009.13	14	100	4,600	679	350	14
1ANOC011.74	1	400	400	400	400	0
Lower South Fork Catoctin Creek						
1ASOC001.66	154	0	8,000	1,684	550	36
1ASOC005.46	3	100	2,200	933	500	33
Upper South Fork Catoctin Creek						
1ASOC005.46	3	100	2,200	933	500	33
1ASOC007.06	12	100	8,000	1,275	250	17
1ASOC008.46	2	100	100	100	100	0
1ASOC011.82	62	3	8,000	1,073	200	24
1ASOC012.38	54	100	8,000	685	100	15
1ASOC014.58	4	100	300	150	100	0
1ASOC015.92	2	100	100	100	100	0
1AXBL000.28	1	3,800	3,800	3,800	3,800	100

[1]Violations are based on FC instantaneous standard (i.e. 1,000 cfu/100ml)

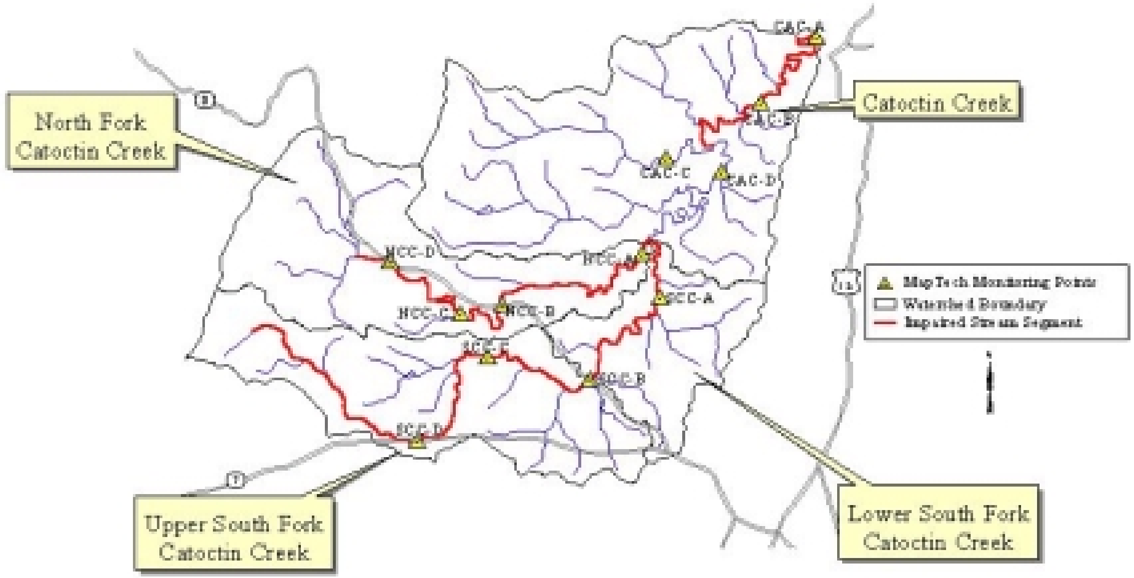

Figure 2.3 Location of MapTech water quality monitoring stations in the Catoctin Creek watershed.

2.2.1.2 Water Quality Monitoring Conducted by MapTech.

As a part of the services provided by MapTech to VADCR, ambient water quality monitoring was performed on six days (8/28/01, 9/24/01, 10/23/01, 11/25/01 12/18/01, and 1/15/02) during the contracted period. Specifically, water quality samples were taken at 12 sites throughout the Catoctin Creek watershed. (Figure 2.3) In addition, a sampling was performed during a 10/15/01 storm event at the outlet of each impairment. All samples were analyzed for fecal coliform and *Enterococci* concentrations, and for fecal type by the Environmental Diagnostics Laboratory at MapTech. Table 2.2 summarizes the fecal coliform concentration data collected by MapTech at the ambient stations. Bacterial source tracking results of water samples collected at the ambient stations are reported in Tables 2.3 – 2.6. Fecal coliform concentrations and bacterial source tracking results of water samples collected during the storm event are listed in Table 2.7. Bacterial source tracking is discussed in greater detail in Section 2.2.2.2.

Table 2.2 Summary of water quality sampling conducted by MapTech. Fecal coliform concentrations (cfu/100 ml).

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] (%)
Catoctin Creek	CAC-A	6	5	1,100	262	120	17
	CAC-B	5	40	2,400	752	160	20
	CAC-C	5	70	2,500	712	240	20
	CAC-D	6	45	950	265	155	0
North Fork Catoctin Creek	NCC-A	6	420	7,000	3,687	3,700	67
	NCC-B	5	160	3,500	2,072	2,000	80
	NCC-C	5	400	9,400	3,338	2,900	60
	NCC-D	6	73	460	329	360	0
Lower South Fork Catoctin Creek	SCC-A	6	200	5,200	2,067	1,575	50
	SCC-B	6	18	1,500	526	460	17
Upper South Fork Catoctin Creek	SCC-C	6	9	6,400	1,270	145	17
	SCC-D	6	5	1,000	356	205	0

[1]Violations based on FC instantaneous standard (i.e. 1,000 cfu/100ml)

Table 2.3 Summary of bacterial source tracking results from water samples collected in the Upper South Fork Catoctin Creek watershed.

Station	Date	FC (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock
SCC-C	08/28/01	900	88	0	13
	09/24/01	6,400	8	92	0
	10/23/01	170	13	33	54
	11/25/01	24	33	46	21
	12/18/01	120	50	13	38
	01/15/02	9	13	6	81
SCC-D	08/28/01	670	83	8	8
	09/24/01	1,000	83	4	13
	10/23/01	320	17	4	79
	11/25/01	50	0	4	96
	12/18/01	91	42	38	21
	01/15/02	5	13	13	75

Table 2.4 Summary of bacterial source tracking results from water samples collected in the Lower South Fork Catoctin Creek watershed.

Station	Date	FC	Percent Isolates classified as:		
		(cfu/100 ml)	Wildlife	Human	Livestock
SCC-A	08/28/01	5,200	67	12	21
	09/24/01	3,500	50	29	21
	10/23/01	2,700	21	8	71
	11/25/01	200	12	25	63
	12/18/01	350	38	29	33
	01/15/02	450	25	37	38
SCC-B	08/28/01	430	75	12	13
	09/24/01	1,500	79	17	4
	10/23/01	600	54	0	46
	11/25/01	18	21	33	46
	12/18/01	490	8	29	63
	01/15/02	120	31	25	44

Table 2.5 Summary of bacterial source tracking results from water samples collected in the North Fork Catoctin Creek watershed.

Station	Date	FC	Percent Isolates classified as:		
		(cfu/100 ml)	Wildlife	Human	Livestock
NCC-A	08/28/01	7,000	67	33	0
	09/24/01	6,100	83	13	4
	10/23/01	6,500	46	46	8
	11/25/01	800	42	33	25
	12/18/01	1,300	58	25	17
	01/15/02	420	21	21	58
NCC-B	08/28/01	2,000	79	0	21
	09/24/01	3,300	75	17	8
	10/23/01	3,500	33	25	42
	11/25/01	160	17	29	54
	12/18/01	1,400	37	46	17
NCC-C	08/28/01	9,400	71	4	25
	09/24/01	2,900	38	50	12
	10/23/01	3,400	42	21	37
	11/25/01	400	4	8	88
	12/18/01	590	38	25	37
NCC-D	08/28/01	440	83	13	4
	09/24/01	300	79	21	0
	10/23/01	280	29	46	25
	11/25/01	420	54	13	33
	12/18/01	460	25	42	33
	01/15/02	73	17	0	83

Table 2.6 Summary of bacterial source tracking results from water samples collected in the Catoctin Creek watershed.

Station	Date	FC (cfu/100 ml)	Percent Isolates classified as: Wildlife	Human	Livestock
CAC-A	08/28/01	140	88	12	0
	09/24/01	1,100	79	8	13
	10/23/01	100	33	13	54
	11/25/01	150	37	17	46
	12/18/01	80	4	33	63
	01/15/02	5	17	46	37
CAC-B	08/28/01	1,000	96	4	0
	09/24/01	2,400	62	13	25
	10/23/01	160	75	4	21
	11/25/01	40	33	13	54
	12/18/01	160	34	8	58
CAC-C	08/28/01	650	50	50	0
	09/24/01	2,500	92	4	4
	10/23/01	70	62	0	38
	11/25/01	240	29	21	50
	12/18/01	100	38	29	33
CAC-D	08/28/01	230	79	13	8
	09/24/01	950	75	0	25
	10/23/01	200	54	8	38
	11/25/01	56	25	38	37
	12/18/01	110	42	12	46
	01/15/02	45	21	29	50

Table 2.7 Summary of water quality sampling results from the 10/15/01 storm event for Catoctin Creek.

Station	Fecal Coliform (cfu/100ml)	Entercocci (cfu/100ml)	% Isolates Classified as Wildlife	Human	Livestock
CAC-A	1,000	550	58	13	29
NCC-A	6,500[1]	3,800	79	0	21
SCC-A	1,700[1]	1,700	54	21	25
SCC-D	1,700[1]	1,100	67	25	8

[1] Violates the FC instantaneous standard (i.e. 1,000 cfu/100ml)

2.2.1.3 Summary of In-stream Water Quality Monitoring Data

A wide range of fecal coliform concentrations have been recorded in the watershed. Concentrations reported by MapTech during the Fall/Winter of 2001-2002 were within the range of historical values reported by VADEQ. Exceedances of the instantaneous standard were reported in all flow regimes, leaving no apparent relationship between flow and water quality.

2.2.2 Analysis of Water Quality Monitoring Data

The data collected were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Results of the analyses are presented in the following sections.

2.2.2.1 Summary of Frequency of Violations at the Monitoring Stations

All water quality data were collected at a time-step of at least one month. The state standard of 1,000 cfu/100 ml was used to test for violations. Samples collected in the Catoctin Creek, North Fork Catoctin Creek, Upper South Fork Catoctin Creek, and Lower South Fork Catoctin Creek exceeded the state water standard 14%, 50%, 8%, and 33% of the time, respectively. A distribution of fecal coliform concentrations at each sampling station in the watershed can be found in Appendix A.

2.2.2.2 Bacterial Source Tracking

MapTech, Inc. was contracted to do in-stream sampling and analysis of fecal coliform concentrations as well as bacterial source tracking. Bacterial source tracking is intended to aid in identifying sources (i.e. human, livestock, or wildlife) of fecal contamination in water bodies. While the short time-frame available, and the subsequent small number of observations taken in this case made drawing conclusions difficult, the data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in bacterial source tracking. The two being developed in Virginia that have shown promise include DNA fingerprinting and biochemical profiling using fecal streptococci. Both procedures are still very much experimental and no studies have yet been completed that compare the methods against each other. For this project, the biochemical profiling method was used to confirm the sources of fecal contamination in streams. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, livestock and wildlife sources in watersheds in Virginia. Compared to DNA fingerprinting, biochemical profiling is much quicker, typically analyzes many more isolates (e.g. 24 vs 10 for DNA analysis), is generally less expensive, has survived limited court testing, and has undergone rigorous peer review from the scientific community. Additionally, observation of an increased number of isolates allows for an estimate of the relative proportions of the fecal indicator (e.g. *Enterococci*) originating from different sources. The results of sampling were reported as the percentage of isolates acquired from the sample that were identified as originating from either human, livestock, or wildlife sources.

Figure 2.4 shows the relationship between fecal coliform concentration at the time of sampling and the percentage of isolates from each source. Results of monitoring in all Catoctin Creek impairments are shown for comparative purposes. Each sample is represented by three symbols, one each representing the proportion of human isolates, livestock isolates and wildlife isolates within that sample. For example, the sample depicted on the far right of the graph indicates a fecal coliform concentration of 9,400 cfu/100 ml with the predominate source of fecal contamination being wildlife (71%), followed by livestock (25%), and then human (4%), while the sample on the far left of the graph indicates a fecal coliform concentration of 18 cfu/100 ml with the predominate source being livestock (46%), followed by human (33%), and then wildlife (21%). Due to the time constraints of the contract, an assessment of seasonal impacts could not be performed on this data.

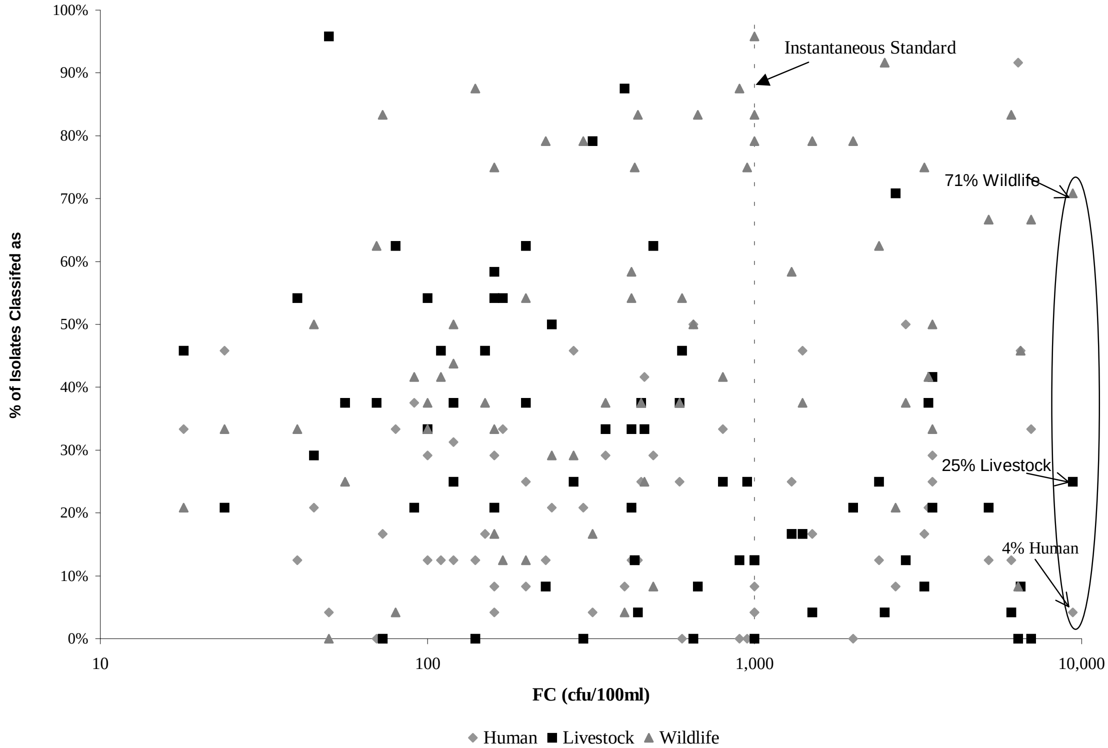

Figure 2.4 Results of in-stream monitoring for fecal coliform concentrations and fecal sources conducted by MapTech.

2.2.2.3 Trend and Seasonal Analyses

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of precipitation, discharge, and fecal coliform concentration data was conducted using the Mood Median Test. This test was used to compare median values of precipitation, discharge, and fecal coliform concentrations in each month. Significant differences between months within years were reported.

2.2.2.4 Precipitation

Total monthly precipitation measured at stations Lincoln and Mount Weather in Loudoun County, Virginia from 4/1968 to 7/2001, was analyzed, and no overall, long-term trend was found. Differences in mean monthly precipitation at Lincoln and Mount Weather are indicated in Tables 2.8 and 2.9, respectively. Precipitations in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, at the Lincoln station, January, February, September, October, November and December are all in median group "A" and are not significantly different from each other. In general, precipitation in the spring-summer months tends to be higher than precipitation in the fall-winter months.

Table 2.8 Summary of the Mood Median Test on mean monthly precipitation at Lincoln.

Month	Mean (in)	Minimum (in)	Maximum (in)	Median Groups[1]	
January	3.00	0.45	7.83	A	
February	2.61	0.22	5.06	A	
March	3.59	0.00	7.07		B
April	3.38	0.42	10.21		B
May	4.10	0.18	9.76		B
June	3.88	0.42	15.07		B
July	3.91	0.39	12.17		B
August	4.11	0.49	14.59		B
September	3.56	0.28	9.73	A	B
October	3.16	0.09	11.26	A	
November	3.17	0.63	7.99	A	B
December	3.12	0.25	6.86	A	

[1] Precipitations in months with the same median group letter are not significantly different from each other at the 95% level of significance.

Table 2.9 Summary of the Mood Median Test on mean monthly precipitation at Mount Weather.

Month	Mean (in)	Minimum (in)	Maximum (in)	Median Groups[1]		
January	2.74	0.29	8.22	A		C
February	2.36	0.44	7.59	A		
March	3.35	0.50	7.43		B	
April	3.35	0.43	8.71	A	B	C
May	4.26	0.56	11.63		B	
June	4.23	1.00	14.31		B	C
July	3.80	0.51	7.90		B	C
August	3.56	0.58	11.46		B	C
September	3.78	1.02	13.12	A	B	C
October	3.40	0.00	12.07	A	B	C
November	3.39	0.41	9.06	A	B	C
December	2.91	0.23	7.56	A	B	C

[1]Precipitations in months with the same median group letter are not significantly different from each other at 95% level of significance.

2.2.2.5 Discharge

Mean monthly discharge measured at USGS Gaging Station #1638480 from 8/1/1971 to 9/30/2000, was analyzed, and an overall, long-term decrease in discharge was observed. The slope of the decrease in mean monthly discharge was estimated at –0.682 cfs/year. The p-value calculated for this test was 0.002, indicating a high level of significance. Much of this overall trend is likely due to a decreasing trend for the months of June and July. The slope of the decrease in mean monthly discharge for June and July was estimated at –1.834 and –1.118 cfs/year, respectively. The p-values calculated for both tests were 0.04 for June and 0.01 for July, indicating a high level of significance. Differences in mean monthly discharge are indicated in Table 2.10. Discharges in months with the same median group letter are not significantly different from each other at the 95% significance level. In general, discharges in the summer-fall months tend to be lower than discharges in the winter-spring months.

Table 2.10 Summary of the Mood Median Test on mean monthly discharge at USGS Station #1638480.

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups[1]			
January	136.09	10.18	487.71				D
February	147.75	21.82	382.04				D
March	190.89	43.71	580.39				D
April	161.52	48.57	476.40				D
May	120.33	26.58	445.06				D
June	89.67	6.82	706.40			C	D
July	47.21	1.35	283.74		B	C	
August	31.54	1.25	185.68	A	B		
September	47.20	1.05	281.07	A			
October	65.94	2.07	413.71	A	B		
November	60.50	5.16	148.00	A	B	C	D
December	114.55	3.88	357.55			C	D

[1]Discharges in months with the same median group letter are not significantly different from each other at the 95% level of significance.

2.2.2.6 Fecal Coliform Concentrations

Water quality monitoring data collected by VADEQ were described in section 2.2.1.1. The trend analysis was conducted on data collected at station 1ACAX004.57 in the Catoctin Creek drainage area. An overall trend in fecal coliform concentrations was detected at this station. A p-value of 0.035 indicates a high level of significance. The significance in the trend may be largely due to decreasing trends for the months of June and September. The slope of the trend for June is –43.095 cfu/100-ml/year, with a p-value of 0.004. The slope of the trend for September is –33.333 cfu/100-ml/year, with a p-value of 0.034. This decreasing trend indicates an improvement in the problem for this station. Table 2.11 summarizes the monthly fecal coliform concentration data collected at station IACAX004.57 in the Catoctin Creek drainage area. No significant difference in monthly fecal coliform within years was detected.

Table 2.11 Summary of mean monthly fecal coliform concentrations measured in the Catoctin Creek watershed at Station 1ACAX004.57.

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100 ml)
January	1,792	93	8,000
February	689	3	3,900
March	1,577	43	24,000
April	546	0	2,500
May	1,849	100	9,200
June	2,066	100	24,000
July	532	23	4,100
August	1,759	43	16,000
September	1,909	100	9,200
October	1,794	100	24,000
November	911	100	4,600
December	2,709	43	24,000

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal coliform in the Catoctin Creek watershed. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in Section 4.

3.1 Assessment of Point Sources

Four point sources are permitted to discharge in the Catoctin Creek watershed through the Virginia Pollutant Discharge Elimination System (VPDES). Permitted point discharges in the Catoctin Creek drainage area include; Hamilton Sewage Treatment Plant, Purcellville Water Treatment Plant, Waterford Sewage Treatment Plant, and one private residence. Figure 3.1 shows their discharge locations. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 ml. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill off any pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. If the concentration is high enough, pathogen concentrations, including fecal coliform concentrations, are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, fecal coliform concentrations are reduced to levels well below the 200 cfu/100 ml limit. Table 3.1 summarizes data from these point discharges.

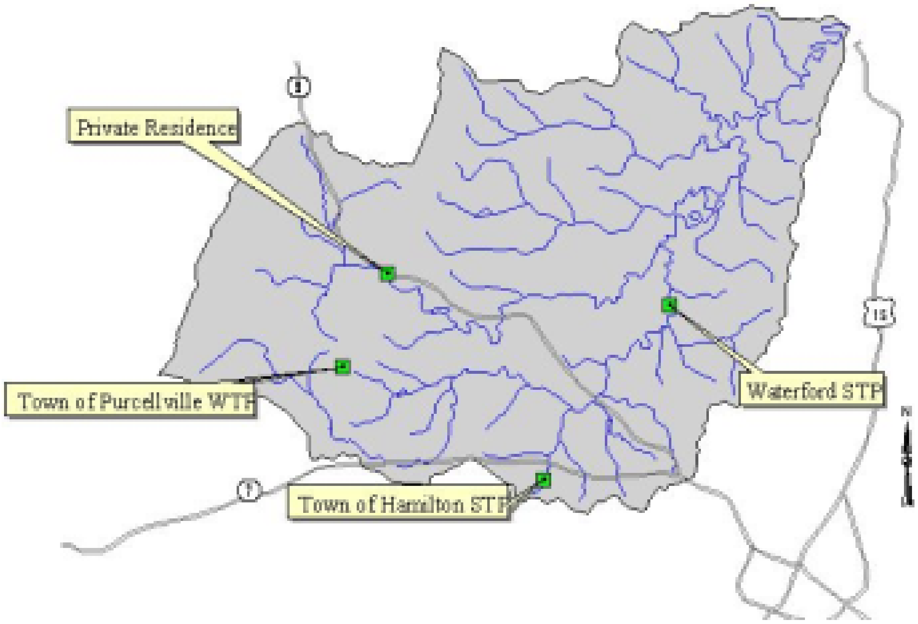

Figure 3.1 Location of VPDES permitted point sources in the Catoctin Creek watershed.

Table 3.1 Summary of VPDES permitted point discharges in the Catoctin Creek watershed.

Facility	VPDES #	Design Discharge (MGD)[1]	Impairment	Permitted for Fecal Control	Data Availability
Hamilton STP	VA0020974	0.16	Upper South Fork Catoctin Creek	Yes	February 1993 - Present
Purcellville WTP	VA0089940	NL[1]	Upper South Fork Catoctin Creek	No	April 1999- Present
Waterford STP	VA0060500	0.058	Lower South Fork Catoctin Creek	Yes	February 1993 - Present
Private Residence	VAG406086	0.001	North Fork Catoctin Creek	Yes	N/A

[1] NL indicates no limitation on discharge volumes.

3.2 Assessment of Nonpoint Sources

In the Catoctin Creek watershed, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech collected samples of fecal coliform sources (i.e. wildlife, livestock, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process, and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.2.2.2). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems that are more than 50 feet from a stream contribute virtually no fecal coliform to surface waters. Reneau (2000) reported that a very small portion of fecal coliform can survive in the soil system for over 50 days. This number might be higher or lower depending on soil moisture and temperature. An analysis of soil system hydrology for soils typical of the area revealed that lateral movement of 50 feet in 50 days would not be unusual. Based on these analyses, it was estimated that properly functioning septic systems within 50 feet of a stream contribute, on average, 0.001% of fecal coliform production.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A permit from the Virginia Department of Health (VDH) is required for installing or repairing a septic system. VDH reported 2,200 permits issued in 2001 for wells, new septic systems, and repairs to septic systems for Loudoun County. Yates (2002) reported that of this number approximately 100 permits were for septic system repairs. A survey of septic pump-out contractors performed by MapTech, showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard. Yates (2002) reported that approximately 25 households were directly depositing sewage to streams.

MapTech sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml. An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

3.2.2 Livestock

The predominant types of livestock in the Catoctin Creek watershed are beef cattle and horses although all types of livestock identified were considered in modeling the watershed. Animal populations were based on communication with Virginia Cooperative Extension Service (VCE), Natural Resources Conservation Service (NRCS), Loudoun County Soil and Water Conservation District (LSWCD), watershed visits, and verbal communication with farmers. Table 3.2 gives a summary of livestock populations in the Catoctin Creek watershed. Values of fecal coliform density of livestock sources were based on sampling performed by MapTech. Reported manure production rates for livestock were taken from ASAE, 1998. A summary of fecal coliform density values and manure production rates is presented in Table 3.3.

Table 3.2 Livestock populations in the Catoctin Creek watershed.

Animal Type	Number of Animals in			
	Upper South Catoctin Creek	Lower South Catoctin Creek	North Fork Catoctin Creek	Catoctin Creek
Dairy				
Milk Cows	0	0	85	0
Dry Cows	0	0	43	0
Replacement Heifers	0	0	42	0
Beef	1,250	550	1,350	2,190
Horse	455	460	685	1,520
Sheep	0	250	130	800
Goat	50	25	0	0
Swine	300	0	0	14

Table 3.3 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	FC Density (cfu/g)
Dairy (1,400 lb)	120.4	258,000
Beef (800 lb)	46.4	101,000
Horse (1,000 lb)	51.0	94,000
Swine (135 lb)	11.3	400,000
Swine Lagoon	N/A	95,300[1]
Sheep (60 lb)	2.4	43,000
Goat (140 lb)	5.7	15,500
Dairy Separator	N/A	32,000[1]
Dairy Storage Pit	N/A	1,200[1]

[1] Units are cfu/100 ml.

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (e.g. pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Second, grazing livestock deposit manure directly on the land, where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams.

One each dairy, beef, and swine producer were identified as collecting and applying a portion of the waste produced on the farm. Time in confinement and estimates of the timing of applications throughout the year was based on data reported by the LSWCD, NRCS, VADCR, and VCE (Table 3.4 and 3.5).

Table 3.4 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total		Land use
	Beef and Swine	Dairy	
January	1.50	0.00	Cropland
February	1.75	0.00	Cropland
March	17.00	20.00	Cropland
April	17.00	20.00	Cropland
May	17.00	20.00	Cropland
June	1.75	0.00	Pasture
July	1.75	0.00	Pasture
August	1.75	0.00	Pasture
September	5.00	0.00	Cropland
October	17.00	20.00	Cropland
November	17.00	20.00	Cropland
December	1.50	0.00	Cropland

Table 3.5 Average time dairy milking cows spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	2.4	0.2	21.4
February	2.4	0.2	21.4
March	3.5	0.3	20.2
April	5.5	0.3	18.2
May	6.4	0.3	17.3
June	6.9	0.4	16.7
July	7.6	0.4	16.0
August	7.6	0.4	16.0
September	7.7	0.3	16.0
October	7.3	0.3	16.4
November	6.4	0.3	17.3
December	4.7	0.2	19.1

All livestock were expected to deposit some portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was reported by the LSWCD, NRCS, VADCR, and VCE (Table 3.6 and Table 3.7). Horses, sheep, donkeys, and goats were assumed to be in pasture 100% of the time.

Based on discussions with LSWCD, VCE, and NRCS, it was concluded that only beef cattle were expected to make a significant contribution through direct deposition to streams. The average amount of time spent by dairy and beef cattle in stream access areas (i.e. within 100 feet of the stream) for each month is given in Table 3.5 through Table 3.7.

Table 3.6 Average time dry cows and replacement heifers spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	22.6	1.4	0
April	21.8	2.2	0
May	21.8	2.2	0
June	21.1	2.9	0
July	21.1	2.9	0
August	21.1	2.9	0
September	21.8	2.2	0
October	22.6	1.4	0
November	22.6	1.4	0
December	23.3	0.7	0

Table 3.7 Average time beef cows spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Feed Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	23.0	1.0	0
April	22.6	1.4	0
May	22.6	1.4	0
June	22.3	1.7	0
July	22.3	1.7	0
August	22.3	1.7	0
September	22.6	1.4	0
October	23.0	1.0	0
November	23.0	1.0	0
December	23.3	0.7	0

3.2.3 Biosolids

In 1996, 268 dry tons of Blue Plains, Bowie and Remington WWTP biosolids, containing approximately 2.14 x 10^{11} cfu of fecal coliform, were applied in the Catoctin Creek drainage area. In 1997, 51 dry tons of Blue Plains WWTP biosolids, containing approximately 4.08 x 10^{10} cfu of fecal coliform, were applied in the Catoctin Creek drainage area. In 1999, 1,202 dry tons of Blue Plains WWTP biosolids, containing approximately 9.59 x 10^{11} cfu of fecal coliform were applied in the Catocin Creek drainage area (VDH, 2001a; VDH, 2001b). The application of biosolids to agricultural lands is strictly regulated in Virginia (VDH, 1997). Biosolids are required to be spread according to sound agronomic requirements and consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). Application rates must be limited to a maximum of 15 dry tons/ac per three year period. Average fecal coliform densities measured from samples collected at Blue Plains WWWTP were 879 cfu/g (VADCR, 2002).

3.2.4 Wildlife

The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), citizens from the watershed, source sampling, and site visits. Population densities were provided by VDGIF and are listed in Table 3.8 (Castanzo, 2002; Farrar, 2002; Knox, 2002; Norman and Lafon, 1998; and Rose and Cranford, 1987). The numbers of animals estimated to be in the Catoctin Creek watershed are reported in Table 3.9. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2002; Norman, 1999; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Costanzo, 2002; Weiskel et al., 1996, and Yagow, 1999). Table 3.10 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife waste performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999). Percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (i.e. within 100 feet of stream) are reported in Table 3.11.

Table 3.8 Wildlife population density.

Animal	Density	Density Unit
Raccoon	0.070	an/ac of habitat
Muskrat	2.751	an/ac of habitat
Beaver	4.800	an/mi of stream
Deer	0.084	an/ac of habitat
Turkey	0.006	an/ac of forest
Goose	0.020	an/ac
Mallard	0.008	an/ac

Table 3.9 Wildlife populations in the Catoctin Creek watershed.

Impairment	Raccoon	Muskrat	Beaver	Deer	Turkey	Goose	Mallard
Upper South Fork Catoctin Creek	318	395	29	1,156	75	286	111
Lower South Fork Catoctin Creek	168	314	23	576	38	141	55
North Fork Catoctin Creek	248	563	42	1,240	82	301	117
Catoctin Creek	590	1578	116	1,942	127	470	182

Table 3.10 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of continuous streams Infrequent = region between 601 and 7,920 ft from continuous streams
Muskrat	100	Primary = region within 66 ft from continuous streams Less frequent = region between 67 and 308 ft
Beaver[1]	200	Continuous stream below 500 ft elevation (defined as distance in feet)
Deer	772	Primary = forested, harvested forest land, orchards, grazed woodland, open urban, cropland, pasture Infrequent = low density residential, medium density residential Seldom/None = rest of land use codes
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland Infrequent = open urban, orchards, cropland, pasture Seldom/None = Rest of land use codes
Goose[3]	225	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and continuous streams
Mallard	150	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and Continuous streams

1 Beaver waste load was calculated as twice that of muskrat, based on field observations.
2 Waste load for domestic turkey (ASAE, 1998).
3 Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2000).

Table 3.11 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

3.2.5 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the watershed and were the only pets considered in this analysis. Cat and dog populations were derived from Lehigh Valley Animal Rights Coalition for United States averages in 1996. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was measured. Fecal coliform density for dogs and cats was measured from samples collected throughout Virginia by MapTech. A summary of the data collected is given in Table 3.12.

Table 3.13 lists the domestic animal populations for the four impairments.

Table 3.12 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	1.7	450	480,000
Cat	2.2	19.4	9

Table 3.13 Domestic animal populations in the Catoctin Creek watershed.

Type	Total Population (an) in			
	Upper South Fork Catoctin Creek	Lower South Fork Catoctin Creek	North Fork Catoctin Creek	Catoctin Creek
Dog	2,863	894	945	2,470
Cat	3,705	1,157	1,223	3,197

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Catoctin Creek watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The stream segment within each subwatershed is simulated as a single reach of open channel, referred to as a RCHRES. Water and pollutants from the land segments (PERLNDs and IMPLNDs) are transported to the RCHRES using mass links. Mass links are also used to connect the modeled RCHRES segments in the same configuration the real stream segments are found in the physical world. The same mass link principal is applied when water and pollutants are conveyed to a RCHRES via a point discharge, or water is withdrawn from a particular RCHRES. On a larger scale, impaired stream segments are also linked to one another by mass links. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the Catoctin Creek drainage area was divided into sixteen subwatersheds (Figure 4.1). The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (i.e. fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Figure 4.1 and Table 4.1). The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. Given this modeling constraint and the desire to maintain a spatial distribution of watershed characteristics and associated parameters, a 15-minute modeling time-step was determined to be required. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

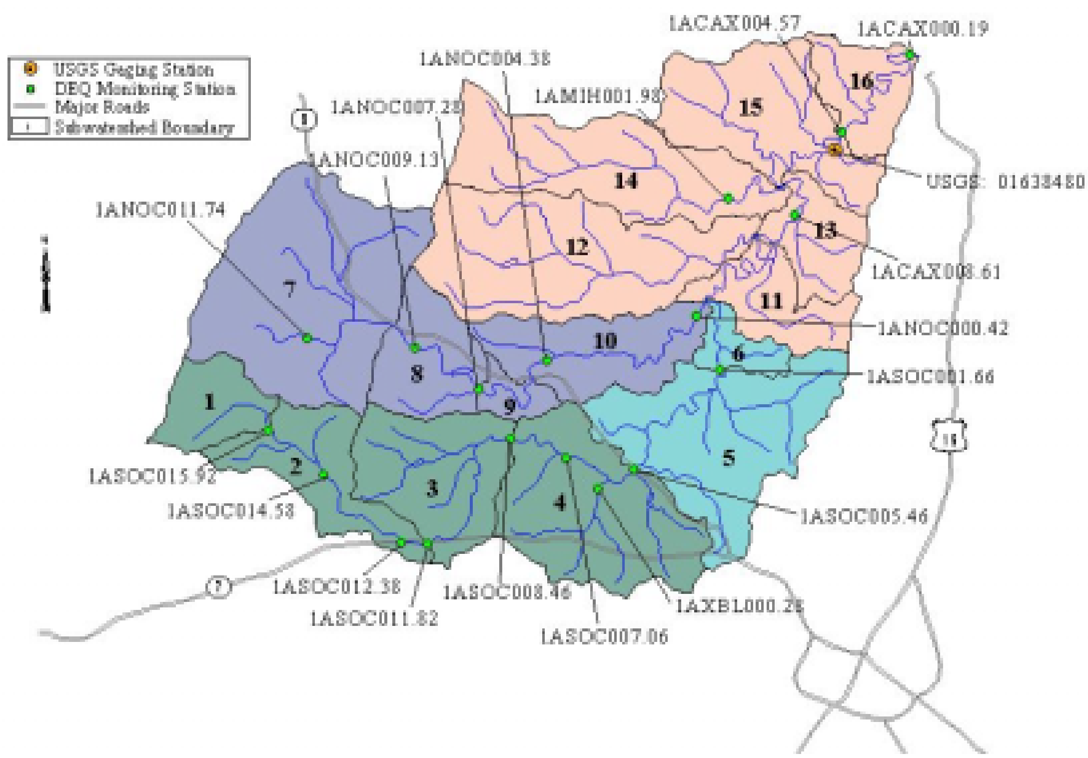

Figure 4.1 Subwatersheds delineated for modeling and location of VADEQ water quality monitoring stations and USGS Gaging Station in the Catoctin Creek watershed.

Table 4.1 VADEQ monitoring stations and corresponding reaches in the Catoctin Creek watershed.

Station Number	Reach Number
1ASOC012.38	2
1ASOC007.06	4
1ASOC001.66	5
1ANOC009.13	7
1ANOC004.38	9
1ANOC000.42	10
1ACAX004.57	15

Using aerial photographs, VADCR identified 18 land use types in the watershed. The 18 land use types were consolidated into 10 categories based on similarities in hydrologic and waste application/production features (Table 4.2). Within each subwatershed, up to the ten land use types were represented. Each land use had parameters associated with it that described the hydrology of the area (e.g. average slope length) and the behavior of pollutants (e.g. fecal coliform accumulation rate). Table 4.3 shows the consolidated land use types and the area existing in each impairment. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in three IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use (Table 4.2). Some IMPLND and PERLND parameters (e.g. slope length) vary with the particular subwatershed in which they are located. Others vary with season (e.g. upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Consolidation of VADCR land use categories for Catoctin Creek watershed.

TMDL Land Use Categories	Pervious / Impervious (Percentage)	VADCR Land Use Categories (Class No.)
Woodland	Pervious (100%)	Forested (4) Orchards (22) Harvested Forest Land (44)
Water	Impervious (100%)	Water (5)
Commercial and Services	Pervious (70%) Impervious (30%)	Commercial & Services (12) Transportation (14)
Residential	Pervious (70%) Impervious (30%)	Open Urban (18) Low Density Residential (111) Medium Density Residential (112) High Density Residential (113)
Cropland	Pervious (100%)	Cropland (211)
Livestock Operations	Pervious (100%)	Cattle Operations (231) Poultry Operations (232) Large dairy waste facilities (242)
Farmstead	Pervious (100%)	Farmstead (241)
Unimproved Pasture	Pervious (100%)	Grazed Woodland (461) Unimproved Pasture (2122)
Improved Pasture	Pervious (100%)	Improved Pasture (2121)
Potential Livestock Access	Pervious (100%)	N/A

[1] Percent perviousness/imperviousness information was used in modeling described in Chapter 4.

Table 4.3 Spatial distribution of land use types in the Catoctin Creek drainage area.

Land Use	Upper South Fork Catoctin Creek Acreage	Lower South Fork Catoctin Creek Acreage	North Fork Catoctin Creek Acreage	Catoctin Creek Acreage
Woodland	3,433	1,639	6,102	6,981
Water	100	48	114	248
Commercial & Services	200	37	2	6
Residential	473	129	83	247
Cropland	2,161	246	934	1,646
Livestock Operations	11	0	0	1
Farmstead	75	32	37	55
Unimproved Pasture	155	125	114	403
Improved Pasture	7,298	4,564	7,318	13,209
Potential Livestock. Access	213	132	152	370

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter, (mechanically applied and deposited directly) die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (i.e. dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (e.g. animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (e.g. population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1995 were used for the water quality calibration and validation period (1993-1997). Data representing 2001 were used for the allocation runs in order to represent current conditions. Additionally, data projected to 2006 were analyzed to assess the impact of changing populations.

4.3.1 Point Sources

There are four permitted point discharges in the Catoctin Creek drainage area. The first Hamilton Sewage Treatment Plant is permitted for fecal control and has a design discharge of 0.16 MGD. Waterford Sewage Treatment Plant is permitted for fecal control and is designed to discharge 0.058 MGD. A private residence is permitted for fecal control with a design discharge of 0.001 MGD. Purcellville Water Treatment Plant is not permitted for fecal control and has no limit on the discharge volume. The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. For calibration and current condition runs, a lower value of fecal coliform concentration was used, based upon a regression analysis relating Total Residual Chlorine (TRC) levels and fecal coliform concentrations. Nonpoint sources of pollution that were not driven by runoff (e.g. direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources as well as land based sources are identified in the following sections.

4.3.2 Private Residential Sewage Treatment

The number of septic systems in the sixteen subwatersheds modeled for the Catoctin Creek watershed was calculated by overlaying Loudoun County Pollution Potential data (2002) with the watershed to enumerate the septic systems. Households were then distributed among farmstead and urban land use types. The total number of households, reported by the 1990 Census, included farmsteads, which were assumed to have septic systems. Septic divisions between urban and farmstead was based on GIS analysis. Each farmstead land use area was assigned a number of septic systems based on census data. A total of 2,640 septic systems were estimated in the Catoctin Creek watershed in 1995. During allocation runs, the number of households was projected to 2001, based on current Loudoun County growth rates (USCB, 2000) resulting in 3,105 septic systems (Table 4.4). The number of septic systems was projected to increase to 3,692 by 2006.

Table 4.4 Estimated failing septic systems.

Watershed	Total Septic Systems	Failing Septic Systems	Straight Pipes
Upper South Fork Catoctin Creek	935	5	3
Lower South Fork Catoctin Creek	407	2	1
North Fork Catoctin Creek	466	2	1
Catoctin Creek	1,297	6	3

4.3.2.1 Functional Septic Systems

Using a procedure developed by MapTech, 1990 Census data (USCB, 1990), overlaid with urban land use and hydrography maps of the watershed, were analyzed to determine the percentage of households with septic systems located within 50 feet of a stream. This number was then projected to 1995, 2001, and 2006. The resulting numbers of septic systems within 50 feet of a stream were 119, 138, and 160, respectively. It was assumed for these homes that 0.001% of the fecal coliform produced in the household would reach the stream through lateral flow. The average number of people per household in each of the sixteen subwatersheds was used to determine the waste load from each house, and the values reported in Section 3.2.1 for human waste load and fecal coliform density were used to determine the fecal coliform load.

4.3.2.2 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. A septic system failure rate of 0.5% was used in development of the TMDL for the Catoctin Creek watershed. This number was calculated by dividing the number of failed systems by the total number of septic systems in the Catoctin Creek watershed, minus straight pipes. The number of permits issued in Loudoun County by VDH for repairs in 2001 was divided by the number of septic systems in the county to determine the percentage of septic failures. A survey of septic pump-out contractors also indicated that the majority of failures occurred at homes that were 20 years old. The total number of failing septic systems in the watershed was therefore distributed among subwatersheds based on the number of homes over 20 years old. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on the survey of septic pump-out contractors to account for more frequent failures during wet months.

4.3.2.3 Uncontrolled Discharges

The number of uncontrolled discharges was estimated to be equal to 0.205% of the number of septic systems in the Catoctin Creek watershed (Section 3.2.1). Since older homes are more likely to have uncontrolled discharges, the number of uncontrolled discharges was distributed among subwatersheds based on the number of homes in each subwatershed that were built more than 30-years prior. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

4.3.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways; land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The number of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2000 were used for the allocation runs, while these numbers were projected back to 1995 for the calibration and validation runs, based on data provided by LSWCD, VADCR, NRCS, and VCE and Loudoun County growth rates determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1995; VASS, 2000). Similarly, when growth was analyzed, livestock numbers were projected to 2006. For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.3). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.3.3.1 Land Application of Collected Manure

Significant collection of livestock manure occurs on various dairy, beef, horse, and swine farms. For each farm in the drainage area, the average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.2. For dairy farms, the amount of waste collected was first based on proportion of milking cows, as the milking herd represented the only cows subject to confinement and therefore waste collection. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. If beef cattle were reported as being confined for some percentage of time, the waste produced while in confinement was added to this total. Finally, values for the percentage of loafing lot waste collected, based on data provided by LSWCD, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.4). Swine were assumed to be in confinement 100% of the time with all waste stored in a lagoon. Stored waste was spread on pastureland. It was assumed that 100% of land-applied waste is available for transport in surface runoff transport unless the waste is incorporated in the soil by plowing during seedbed preparation. Percentage of cropland plowed and amount of waste incorporated was adjusted using calibration for the months of planting.

4.3.3.2 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the livestock inventory conducted by Ferrum College and reported by MapTech (1999a), unpublished research data by Virginia Tech, and consultation with LSWCD, NRCS, and VCE. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse, sheep, donkey, and goat) were assumed to deposit all feces on pasture. Pasture land use types were divided into improved and unimproved pasture. The total amount of fecal matter deposited on each of these land-use types was area-weighted.

4.3.3.3 Direct Deposition to Streams

Beef cattle are the primary sources of direct deposition by livestock in the Catoctin Creek watershed. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in “stream access” areas was calculated based on the livestock inventory conducted by Ferrum College and reported by MapTech (1999), unpublished research data by Virginia Tech, and consultation with LSWCD, NRCS, and VCE. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 70% of the waste was modeled as being directly deposited in the stream and 30% remained on the land segment adjacent to the stream. The 30% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 70% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.3.4 Biosolids

Investigation of VDH data indicated that in 1996, 1997, and 1999 approximately 92, 12.2, and 139.8 acres, respectively, received biosolids applications in Loudoun County. For model calibration, no biosolids were modeled. With urban populations growing, the disposal of biosolids will take on increasing importance. Class B biosolids have been measured with 68,467 cfu/g-dry and are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. The sensitivity analysis provided insight into the effects that increased applications of biosolids could have on water quality.

4.3.5 Wildlife

For each species, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.4). An example of one of these layers is shown in Figure 4.2. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

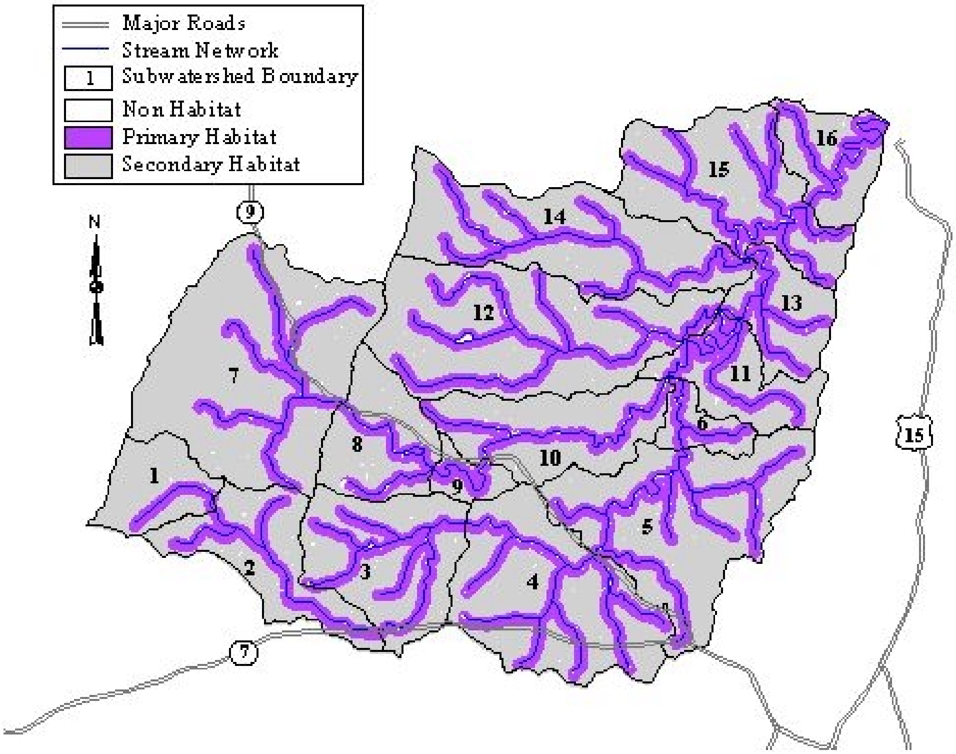

Figure 4.2 Example of raccoon habitat layer developed by MapTech in the Catoctin Creek watershed.

Seasonal distribution of waste was determined using seasonal food preferences for deer and turkey. Goose and duck populations were varied based on migration patterns. No seasonal variation was assumed for the remaining species. For each species, a portion of the total waste load was considered to be land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.11). It was estimated that for all animals other than beaver that 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. To account for un-quantifiable fecal coliform loads from known wildlife species, a background load was applied to all land segments at 10% of the total land-based wildlife load, and the total direct-deposition wildlife load was increased by 10%. No long-term (1995–2006) adjustments were made to wildlife populations, as there was no available data to support such adjustments.

4.3.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals/house), waste load, and fecal coliform density are reported in Section 3.2.5. Waste from pets was distributed in the urban and farmstead land uses. The location of households was taken from the 1990 Census (USCB, 1990). The land use and household layers were overlaid which resulted in number of households per land use. The number of animals per land use was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each land use segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1995, 2001, and 2006 based on human population growth rates.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (e.g. stream geometry and resistance to flow). In order to determine a representative stream profile for each stream reach, cross-sections were surveyed at the subwatershed outlets. One outlet was considered the beginning of the next reach, when appropriate. In the case of a confluence, sections were surveyed above the confluence for each tributary and below the confluence on the main stream.

Most of the sections exhibited distinct flood plains with pitch and resistance to flow significantly different from that of the main channel slopes. The streambed, channel banks, and flood plains were identified. Once identified, the streambed width and slopes of channel banks and flood plains were calculated using the survey data. A representative stream profile for each surveyed cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.3). With this approach, the flood plain can be represented differently from the streambed. To represent the entire reach, profile data collected at each end of the reach were averaged.

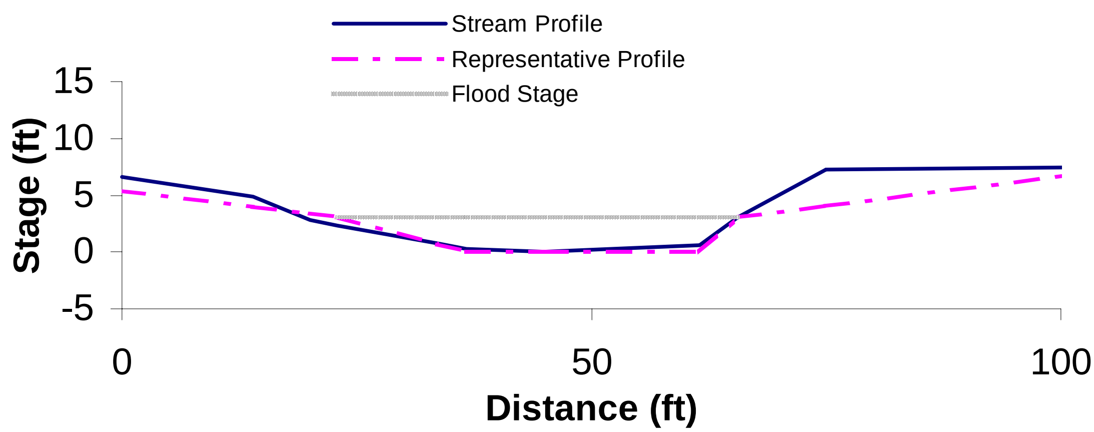

Figure 4.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with different values for resistance to flow (Manning's n) assigned to the flood plains and streambeds. The conveyance was calculated for each of the two flood plains and the main channel, then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth.

A key parameter used in the calculation of conveyance is the Manning's roughness coefficient, n. There are many ways to estimate this parameter for a section. The method first introduced by Cowan (1956) and adopted by the Soil Conservation Service (1963) was used to estimate Manning's n. This procedure involves a 6-step process of evaluating the properties of the reach, which is explained in more detail by Chow (1959). Field data describing the channel bed, bank stability, vegetation, obstructions, and other pertinent parameters were collected. Photographs were also taken of the sections while in the field. Once the field data were collected, they were used to estimate the Manning's roughness for the section observed. The pictures were compared to pictures contained in Chow (1959) for validation of the estimates of the Manning's n for each section.

The result of the field inspections of the reach sections was a set of characteristic slopes (channel sides and field plains), bed widths, heights to flood plain, and Manning's roughness coefficients. Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network digitized from USGS 7.5-minute quadrangle maps (scale 1:24,000). These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.5). The F-tables developed consist of four columns; depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. A maximum depth of 50 ft was used in the F-tables. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

Table 4.5 Example of an "F-table" calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0.0	21.75	0.00	0.00
0.2	21.96	4.37	10.87
0.4	22.16	8.78	34.54
0.6	22.36	13.23	67.92
0.8	22.56	17.73	109.75
1.0	22.77	22.26	159.29
1.3	23.07	29.14	246.88
1.7	23.48	38.44	386.59
2.0	23.78	45.53	507.43
2.3	24.08	52.71	641.30
2.7	24.49	62.43	839.20
3.0	24.79	69.82	1,001.68
6.0	29.42	149.62	3,222.35
9.0	37.08	249.37	6,254.60
12.0	44.73	372.08	10,078.05
15.0	52.38	517.75	14,818.37
25.0	77.32	1,163.48	38,629.43
50.0	92.02	2,796.19	103,246.75

4.5 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors; availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station #01638480 was available from July 1971 to September 2000. The modeling period was selected to include the VADEQ assessment period from July 1992 through June 1997 that led to the inclusion of the Catoctin segments on the 1998 Section 303 (d) list. The fecal concentration data from this period were evaluated for use during calibration and validation of the model. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Using observed data that is reported at a shorter time-step improves this process and subsequently the performance of a time-dependent model. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration. During validation, no adjustments are made to model parameters. The goal of validation is to assess the capability of the model in hydrologic conditions other than those used during calibration.

High concentrations of fecal coliform were recorded in all flow regimes, and a period for calibration and validation was chosen based on the overall distribution of wet and dry seasons. The mean daily flow and precipitation for each season were calculated for the period July 1971 through September 2000. This resulted in 29 observations of flow for each season. The mean daily precipitation for each season was calculated for the period January 1930 through July 2001. This resulted in 65 observations of precipitation each season. The mean and variance of these observations were calculated. Next, a representative period for modeling was chosen and compared to the historical data. The initial period was chosen based on the availability of mean discharge data closest to the fecal coliform assessment period (1/90-12/00). The representative period was chosen such that the mean and variance of each season in the modeled period was not significantly different from the historical data (Table 4.6). Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting period for hydrologic calibration was October 1990 through September 1995. For hydrologic validation, the period selected was October 1995 through September 1999.

Table 4.6 Comparison of modeled period to historical records.

	Mean Flow (cfs)				Precipitation (in/day)			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1971-2000)				**Historical Record (1930-2001)**			
Mean	81	159	124	43	0.105	0.094	0.130	0.124
Variance	3,879	7,790	5,724	2,084	0.001	0.001	0.002	0.002
	Calibration & Validation Period (10/90-9/95, 10/95-9/99)							
Mean	83	203	102	34	0.110	0.119	0.125	0.126
Variance	5,071	14,695	2,961	2,366	0.001	0.002	0.002	0.003
	P-Values							
Mean	0.460	0.159	0.175	0.321	0.349	0.062	0.378	0.457
Variance	0.280	0.102	0.167	0.370	0.468	0.084	0.335	0.099

4.6 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Qualities of fecal coliform sources were modeled as described in chapters 3 and 4. Through calibration these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.6.1 Hydrologic Calibration and Validation

Parameters that were adjusted during the hydrologic calibration represented the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), and the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), forest coverage (FOREST), slope of overland flow plane (LSUR), groundwater recession flow (KVARY), maximum and minimum air temperature affecting PET (PETMAX, PETMIN, respectively), infiltration equation exponent (INFEXP), infiltration capacity ratio (INFILD), active groundwater storage

PET (AGWETP), Manning's n for overland flow plane (NSUR), interception (RETSC), weighting factor for hydraulic routing (KS). Table 4.7 contains the typical range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

The model was calibrated for hydrologic accuracy using 15-minute flow data from USGS Station #01638480 for the period October 1990 through September 1995 (Table 4.8). Results for the entire calibration period are plotted in Figure 4.4. Water year 1992 is represented in Figure 4.5 to portray the model performance on an annual scale.

Table 4.7 Model parameters utilized for hydrologic calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
FOREST	---	0.0 – 0.95	0.0	0.0
LZSN	in	2.0 – 15.0	14.2	12.0
INFILT	in/hr	0.001 – 0.50	0.1 – 0.3	0.025 – 0.075
LSUR	ft	100 – 700	32 – 1467	32 –1467
SLSUR	---	0.001 – 0.30	0.015 – 0.213	0.015 – 0.213
KVARY	l/in	0.0 – 5.0	0.0	0.0
AGWRC	l/day	0.85 – 0.999	0.98	0.95
PETMAX	degF	32.0 – 48.0	40.0	40.0
PETMIN	degF	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.0	0.0
BASETP	---	0.0 – 0.20	0.0	0.02 – 0.07
AGWETP	---	0.0 – 0.20	0.0	0.0
CEPSC	in	0.01 - 0.40	0.05 – 0.20	0.021 - 0.375
UZSN	in	0.05 – 2.0	0.65 – 1.46	0.118 – 1.329
NSUR	---	0.10 – 0.50	0.1 – 0.4	0.048 – 0.576
INTFW	---	1.0 – 10.0	0.56 – 1.69	2.0
IRC	l/day	0.30 – 0.85	0.55 – 0.62	0.55 – 0.62
LZETP	---	0.1 – 0.9	0.5 – 0.8	0.189 – 0.960
RETSC	in	0.0 – 1.0	0.001 – 0.05	0.001 – 0.05
KS	---	0.0 – 0.9	0.5	0.5

Table 4.8 Hydrology calibration criteria and model performance for period 10/1/90 through 9/30/95.

Criterion	Simulated	Observed	% Error
Total annual runoff (in)	69.92	67.62	3.40
Low flow recession rate	0.93	0.94	-1.06
Total of highest 10% of flows (in)	36.83	36.05	2.16
Total of lowest 50% of flows (in)	6.14	5.69	7.91
Total storm volume (in)	10.92	9.62	13.51
Summer flow volume (in)	5.50	5.14	7.00
Winter flow volume (in)	28.91	25.17	14.86
Summer storm volume (in)	0.47	0.46	2.17

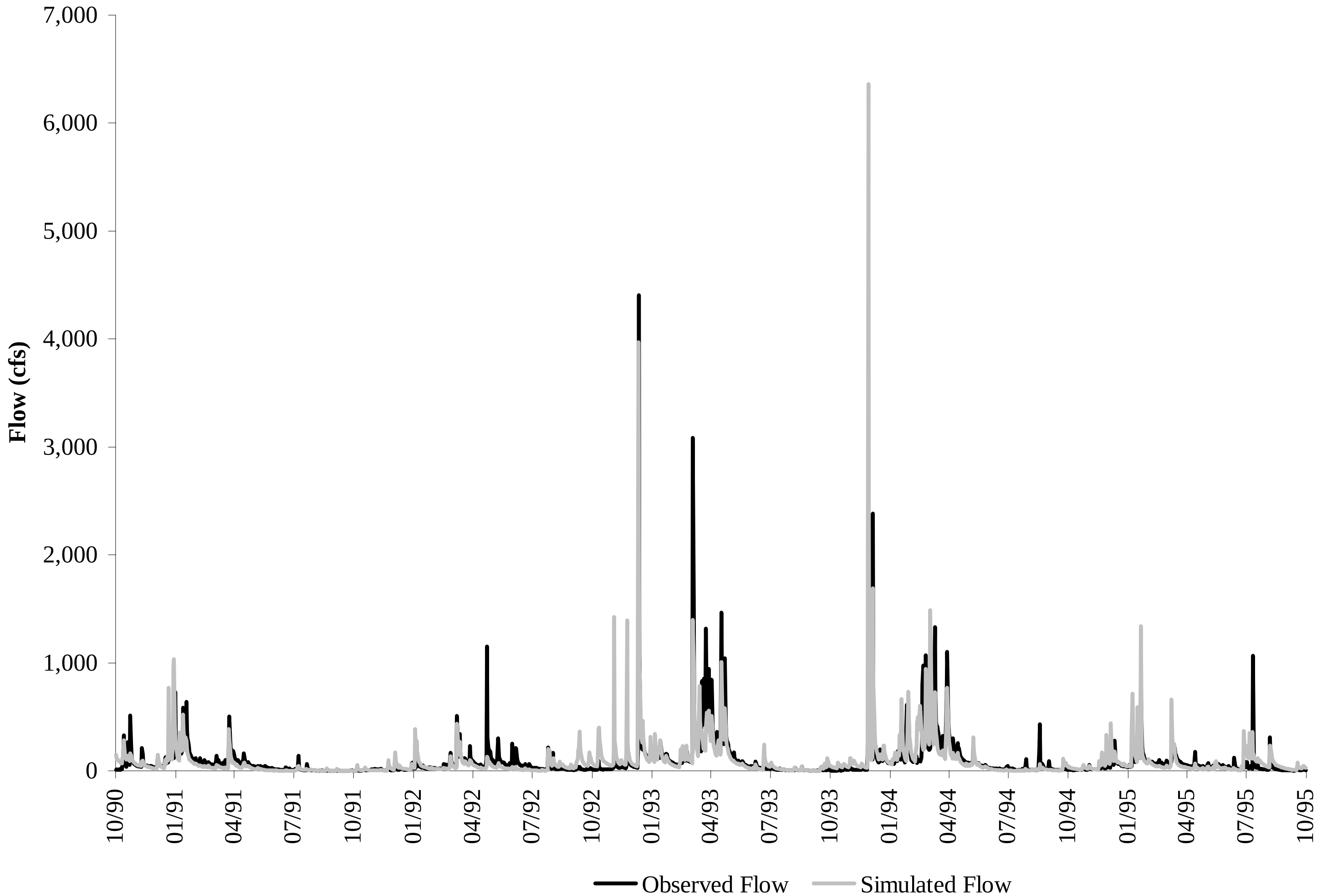

Figure 4.4 Calibration results for period 10/1/90 through 10/1/95.

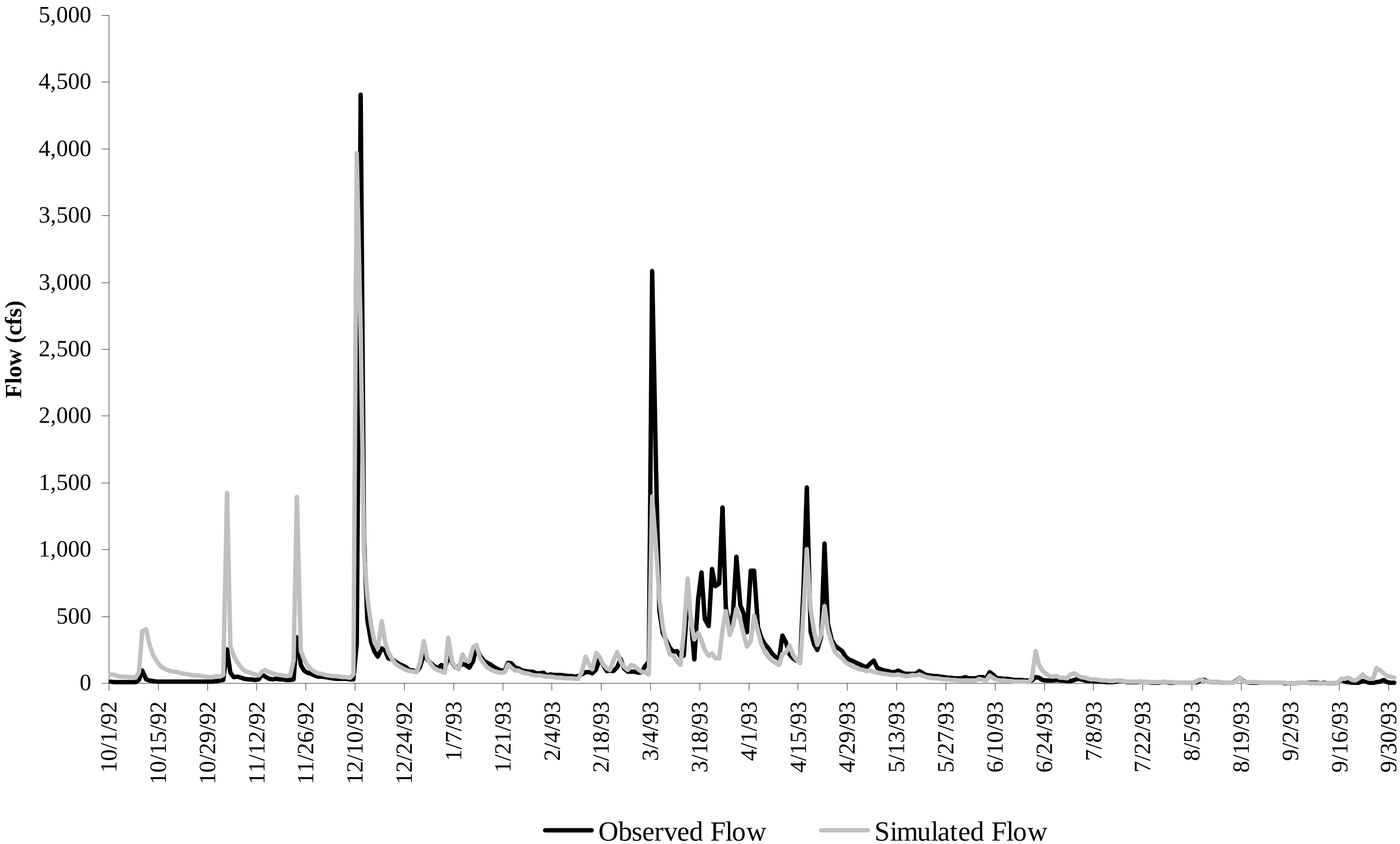

Figure 4.5 Calibration results for period 10/1/92 through 9/30/93.

The model was validated for the period October 1995 through September 1999 (Table 4.9). Validation results are included in Figure 4.6. Water year 1997 is represented in Figure 4.7 to portray the model performance on an annual scale. It was decided to use 15-minute precipitation during the validation period in order to make a comparable evaluation of the model response with respect to the model response during the hydrology calibration period. However, starting in January 1998, only daily precipitation values were available. As a result, daily precipitation values from January 1998 to September 1999 were transformed to 15-minute values using an SCS-Type II storm distribution. Precipitation was distributed throughout the day, thereby lessoning the precipitation intensity. The transformation resulted in an overestimation of low flows and an underestimation of high flows during January 1998 to September 1999 that translated into the overall statistics for the validation period.

Table 4.9 Hydrology validation criteria and model performance for validation period 10/1/95 through 9/30/99.

Criterion	Simulated	Observed	% Error
Total annual runoff (in)	68.48	71.27	-3.91
Low flow recession rate	0.94	0.95	-0.01
Total of highest 10% of flows (in)	29.97	34.24	-12.47
Total of lowest 50% of flows (in)	7.80	5.63	38.54
Total storm volume (in)	5.39	6.59	-18.21
Summer flow volume (in)	9.75	8.16	19.48
Winter flow volume (in)	24.12	27.59	-12.58
Summer storm volume (in)	1.51	1.77	-14.69

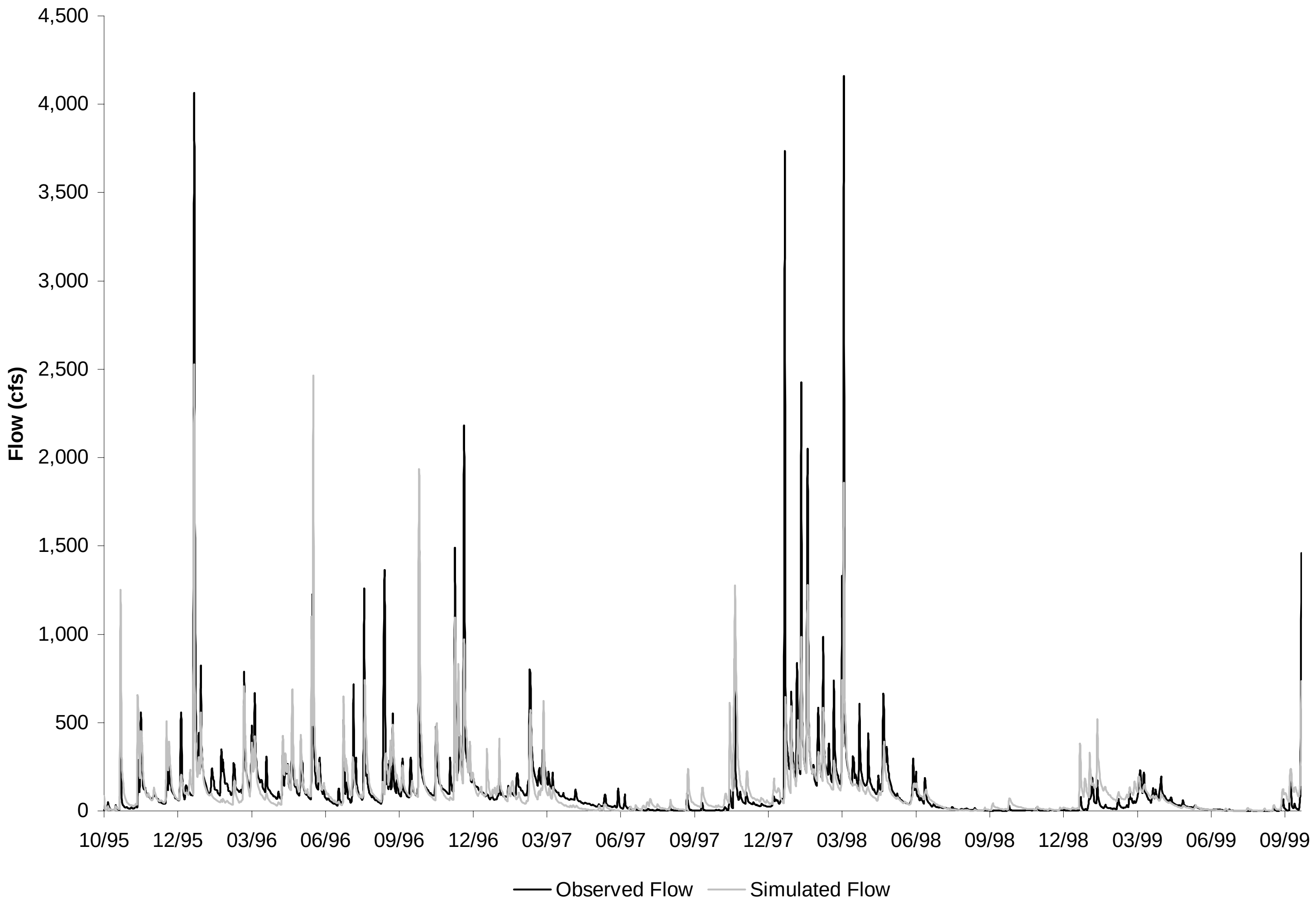

Figure 4.6 Validation results for period 10/1/95 through 9/30/99.

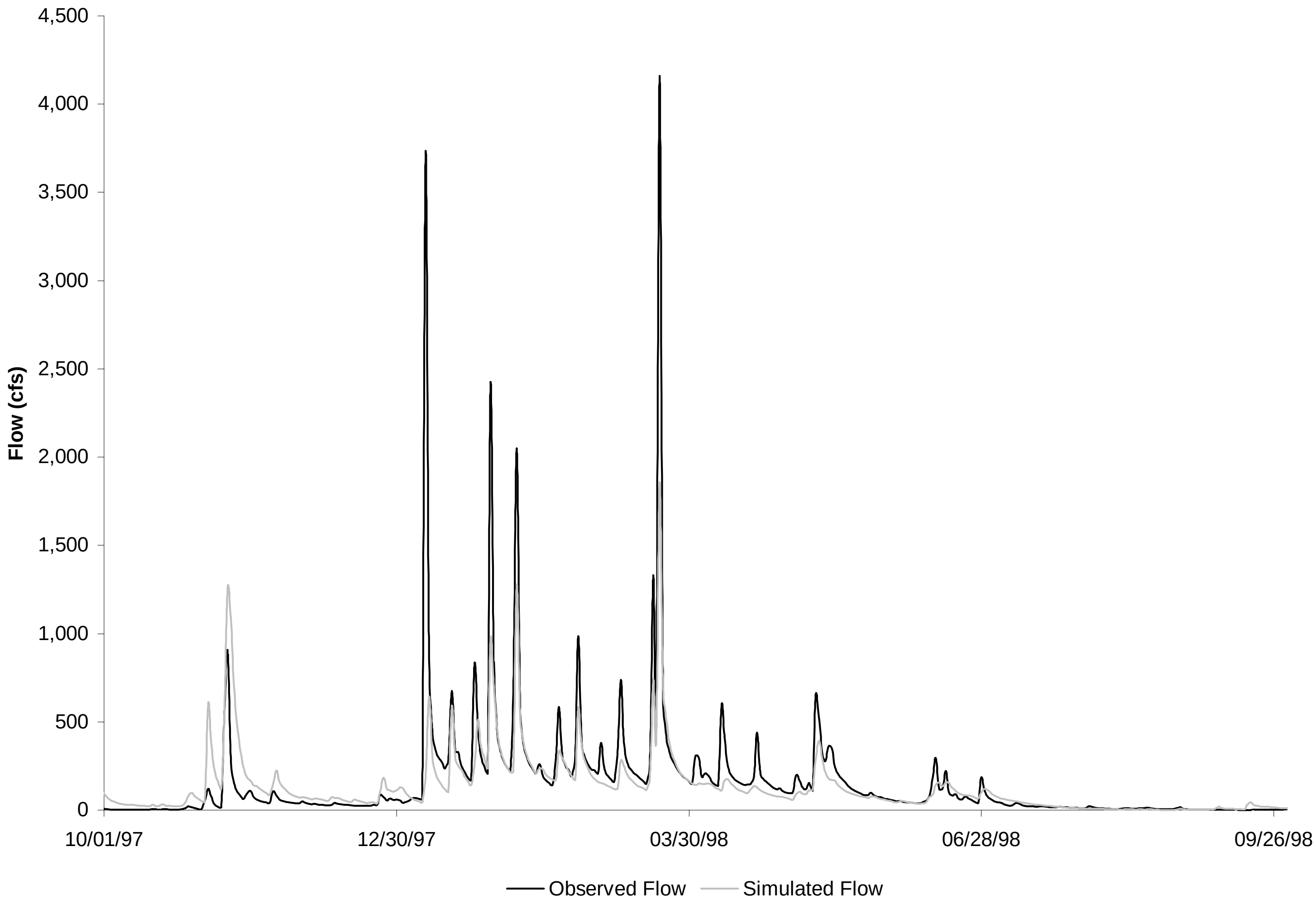

Figure 4.7 Validation results for period 10/1/97 through 9/30/98.

4.6.2 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (e.g. fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the limited amount of measured data for use in calibration and the practice of censoring both high (over 24,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

The water quality calibration was conducted from 1/1/93 through 12/31/95. Four parameters were utilized for model adjustment; in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP), and concentration of fecal coliform in interflow (IOQC). All these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.10). Figure 4.8, Figure 4.9, and Figure 4.10 show the results of calibration. Short-period fluctuations in the modeled data denotes the effective modeling of the variability within daily concentrations that was achieved through distributing direct depositions from wildlife, livestock, and uncontrolled discharges across each day (Section 4.3).

Table 4.10 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-ACCUM	FC/ac*day	0.0E+00 – 1.0E+20	2.1E+07 – 2.9E+11	2.1E+07 – 2.9E+11
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	3.0E+07 – 3.5E+12	4.2E+07 – 1.0E+12
WSQOP	in/hr	0.05 – 3.00	1.50	1.00
MON-IFLW-CON	FC/ft^3	0.0E+00 – 1.0E+06	6.0E+00 – 1.6E+03	6.0E+00 – 1.6E+03
AOQC	FC/ft^3	0 – 10	0	0
DQAL	FC/100ml	0 – 1,000	1 – 408	1 – 408
FSTDEC	1/day	0.01 – 10.00	0. 60	0.20 – 5.35
THFST	---	1.0 – 2.0	1.07	1.07

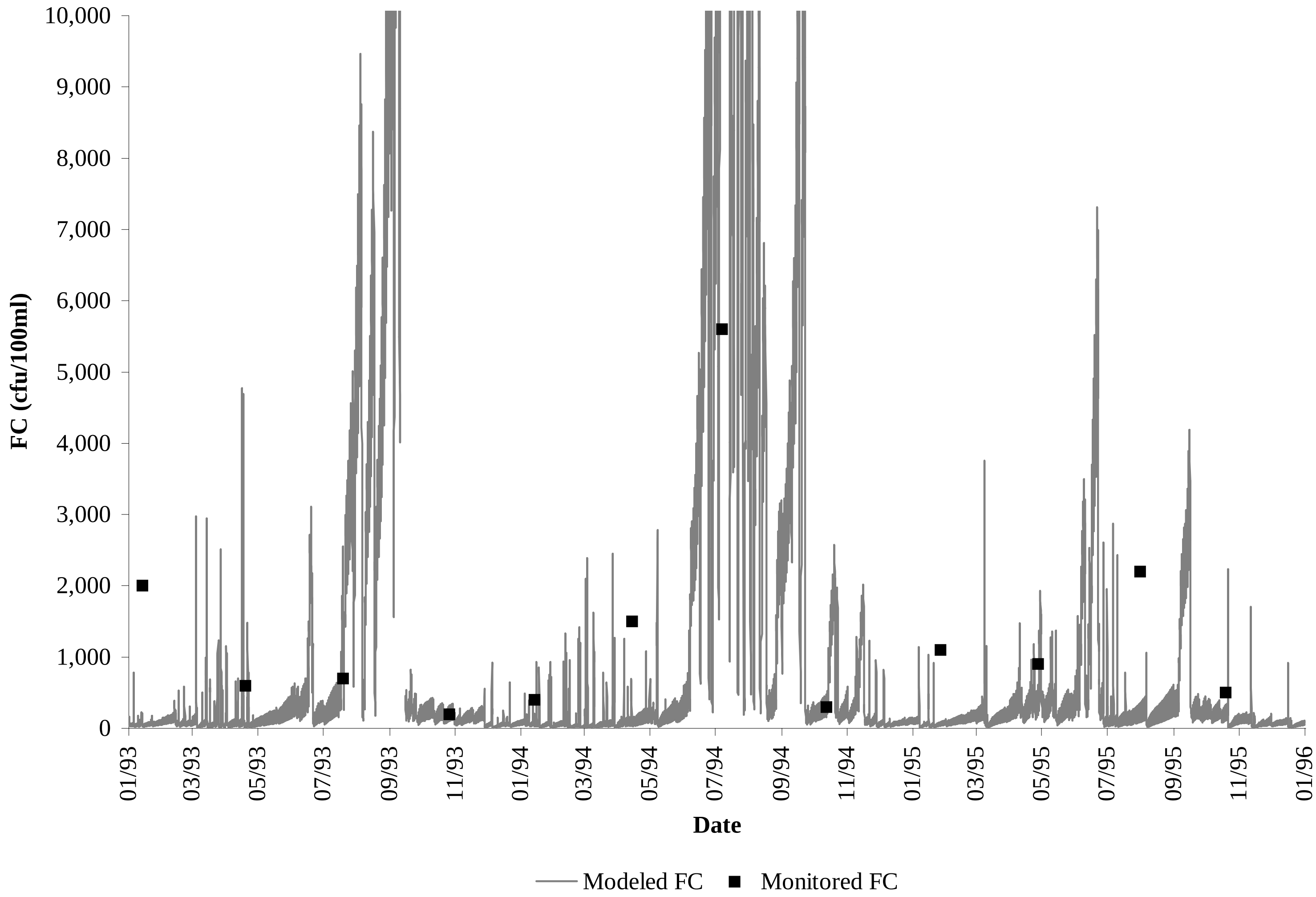

Figure 4.8 Quality calibration for subwatershed 5 in Lower South Fork Catoctin Creek impairment.

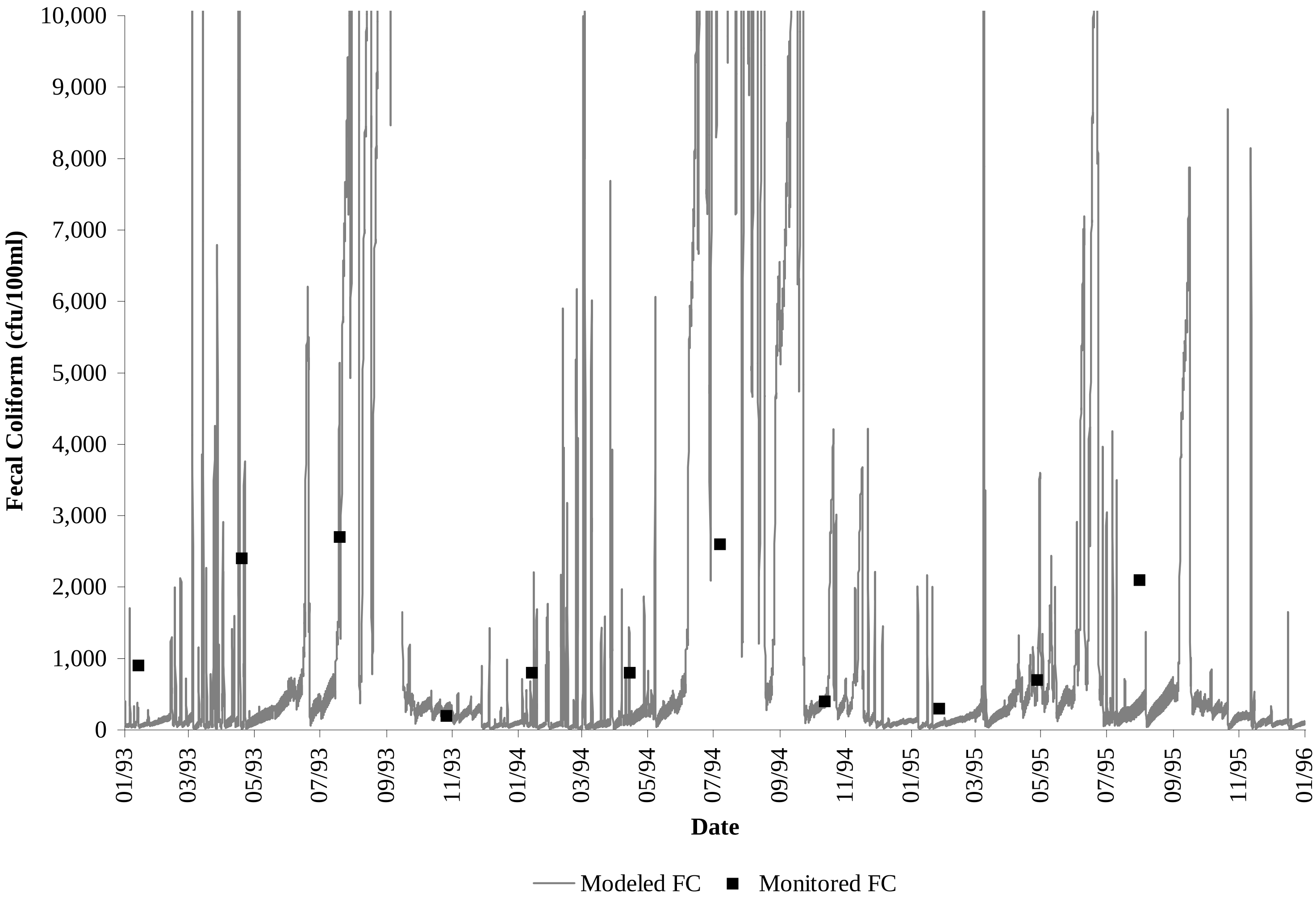

Figure 4.9 Quality calibration for subwatershed 10 in North Fork Catoctin Creek impairment.

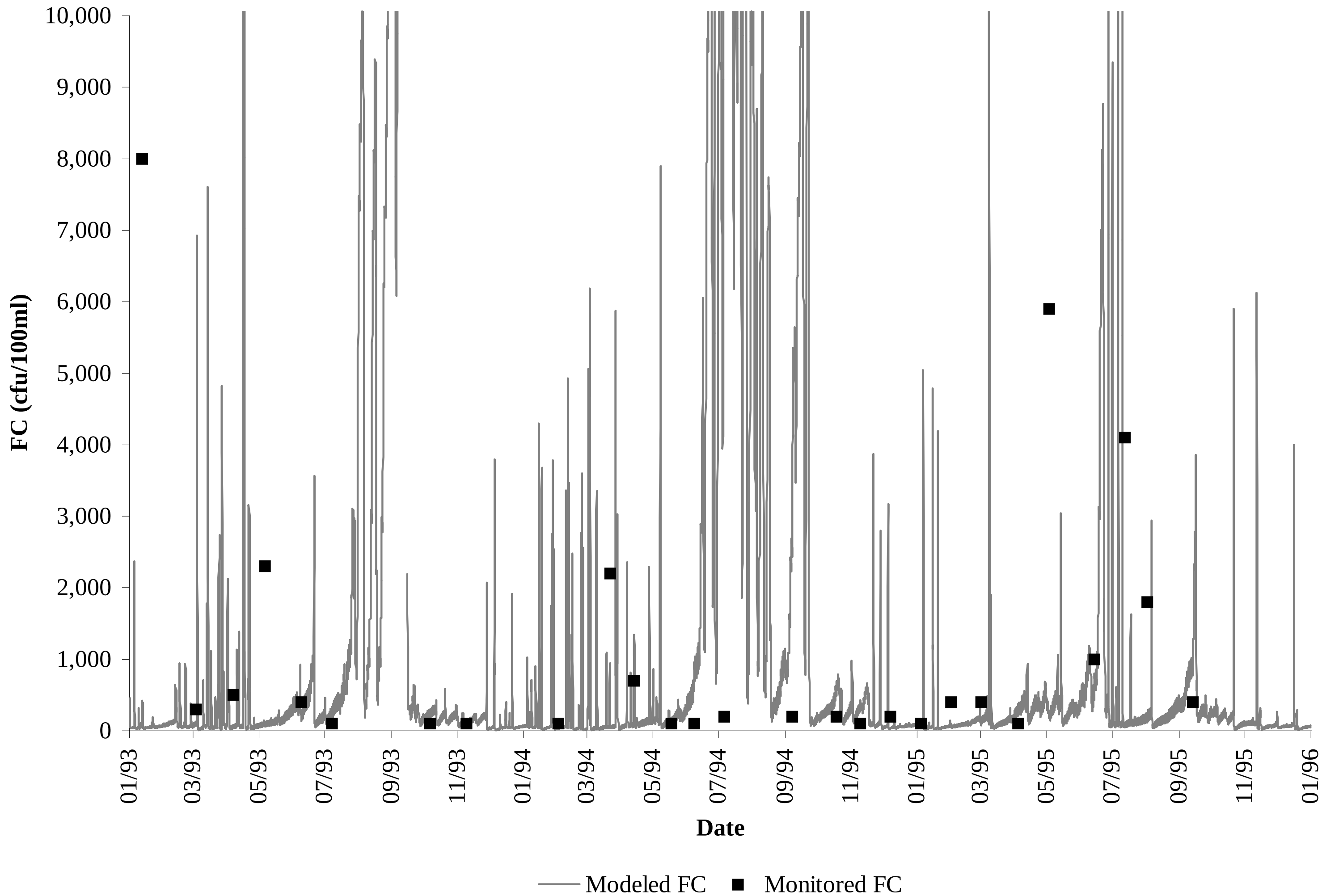

Figure 4.10 Quality calibration for subwatershed 15 in Catoctin Creek impairment.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. First, the minimum and maximum modeled values in each modeled window was determined. Figure 4.11 through Figure 4.13 show the relationship between these extreme values and observed data. In addition, standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}\left(observed - modeled_i\right)^2}{(n-1)}}}{\sqrt{n}}$$

where

$$\begin{aligned} observed &= \text{an observed value of fecal coliform} \\ modeled_i &= \text{a modeled value in the 2-day window surrounding the observation} \\ n &= \text{the number of modeled observations in the 2-day window} \end{aligned}$$

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and therefore increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data (Section 2) and found to be at reasonable levels (Table 4.11).

Table 4.11 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
1ASOC001.66	124.53	107,740
1ACAX004.57	64.71	171,870

The water quality validation was conducted for the time period from 1/1/98 to 12/31/00. The relationship between observed values and modeled values can be seen in Figure 4.14 through Figure 4.21.

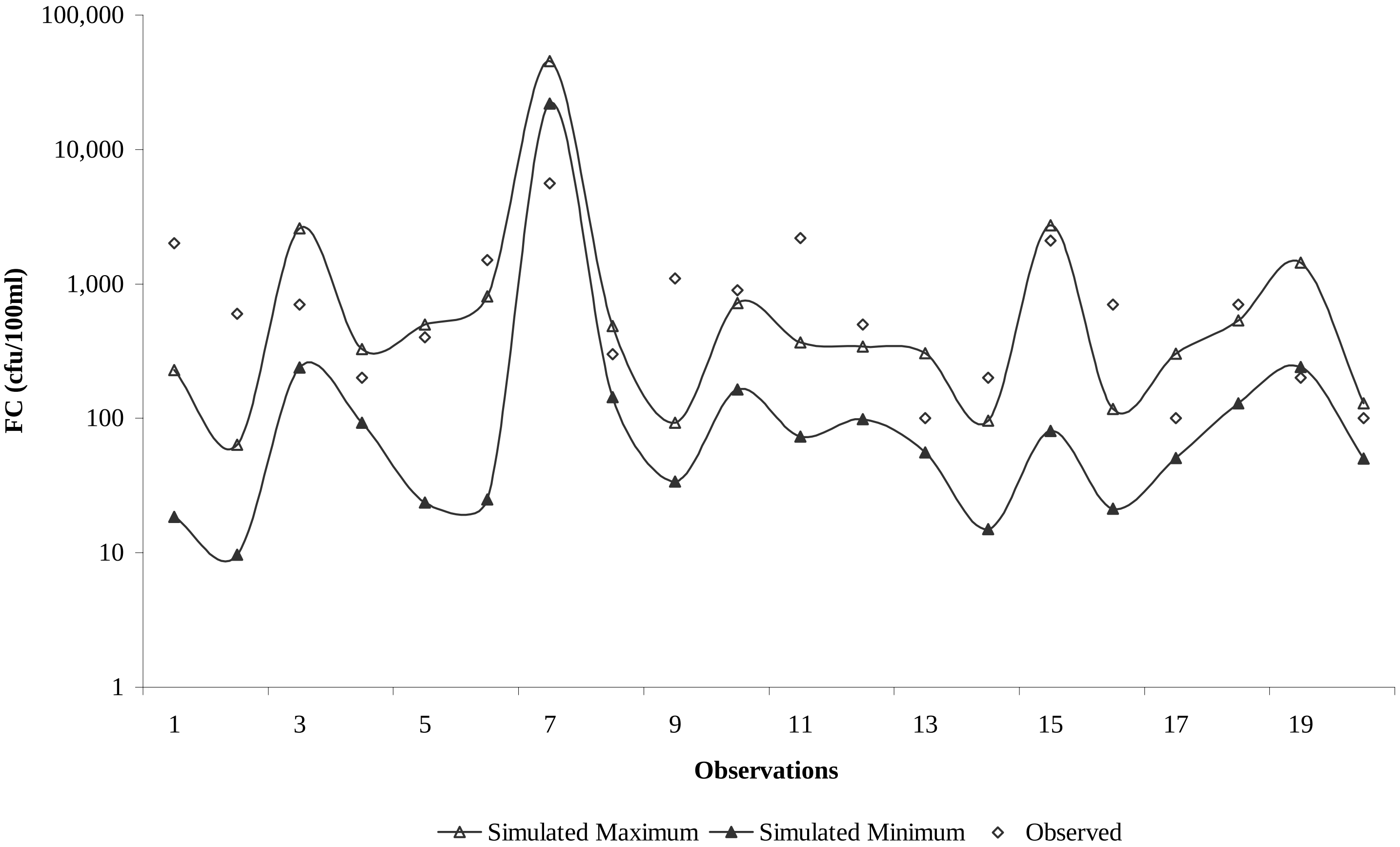

Figure 4.11 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 5 in Lower South Fork Catoctin Creek impairment.

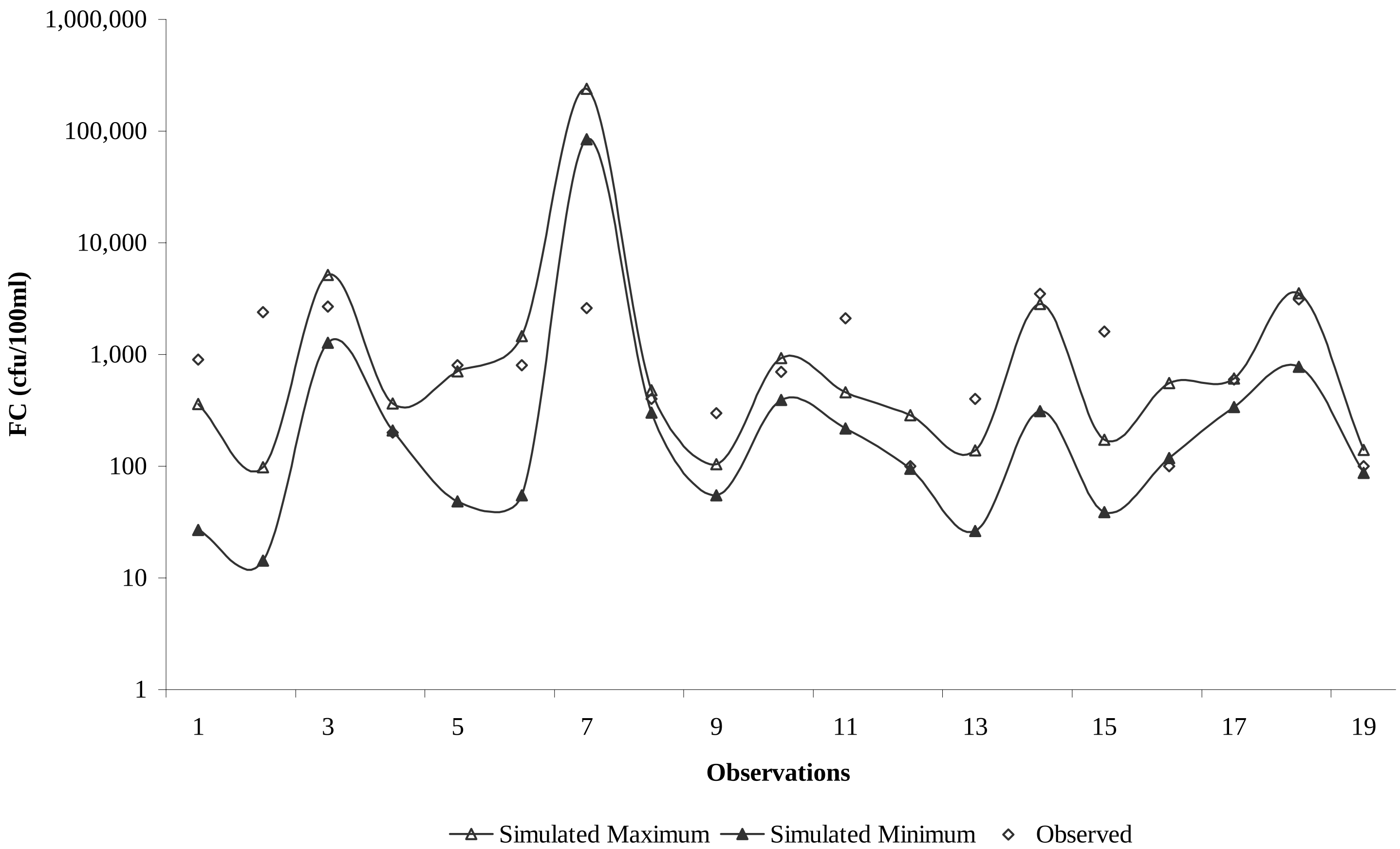

Figure 4.12 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 10 in North Fork Catoctin Creek impairment.

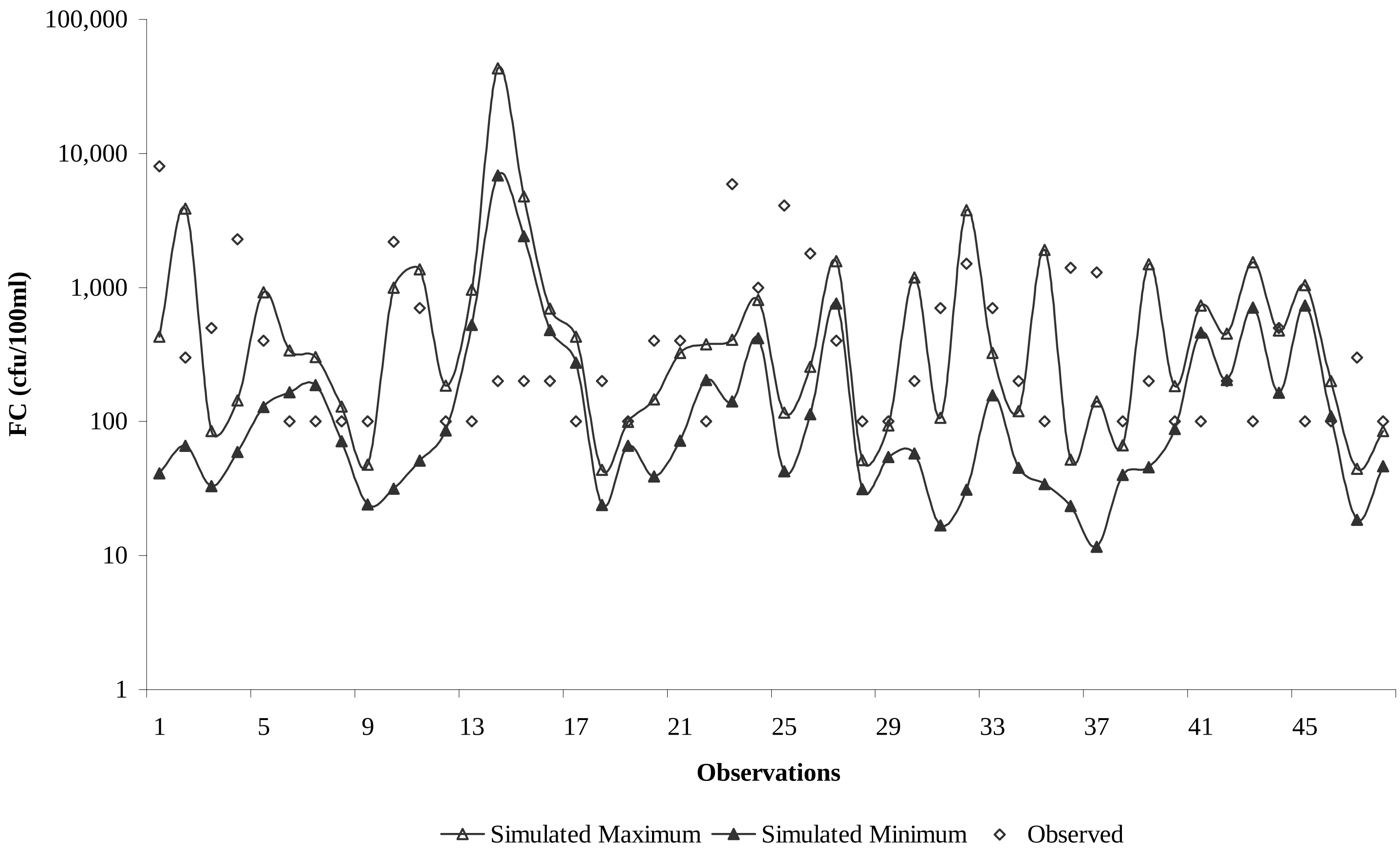

Figure 4.13 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 15 in Catoctin Creek impairment.

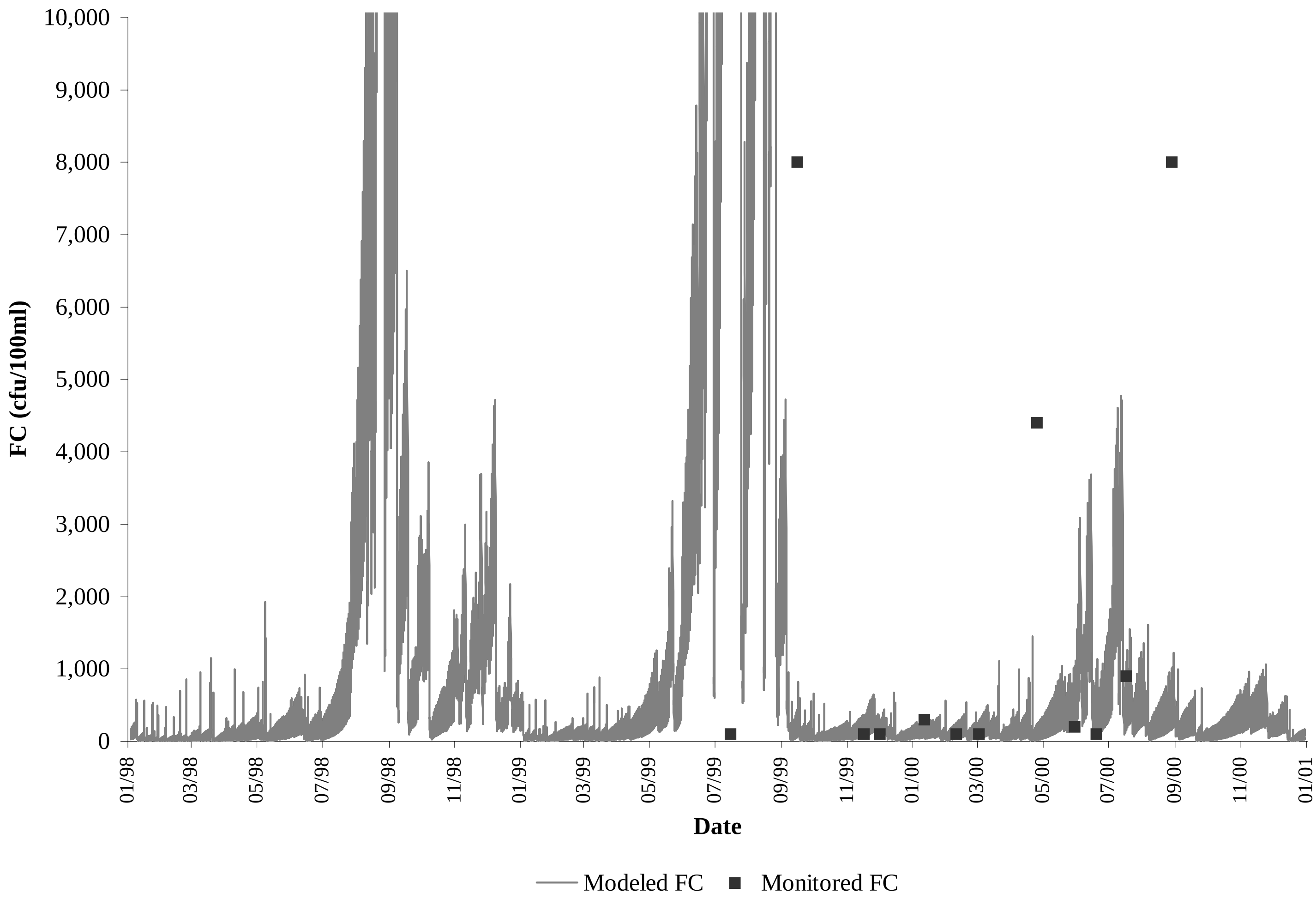

Figure 4.14 Quality validation for subwatershed 2 in Upper South Fork Catoctin Creek impairment.

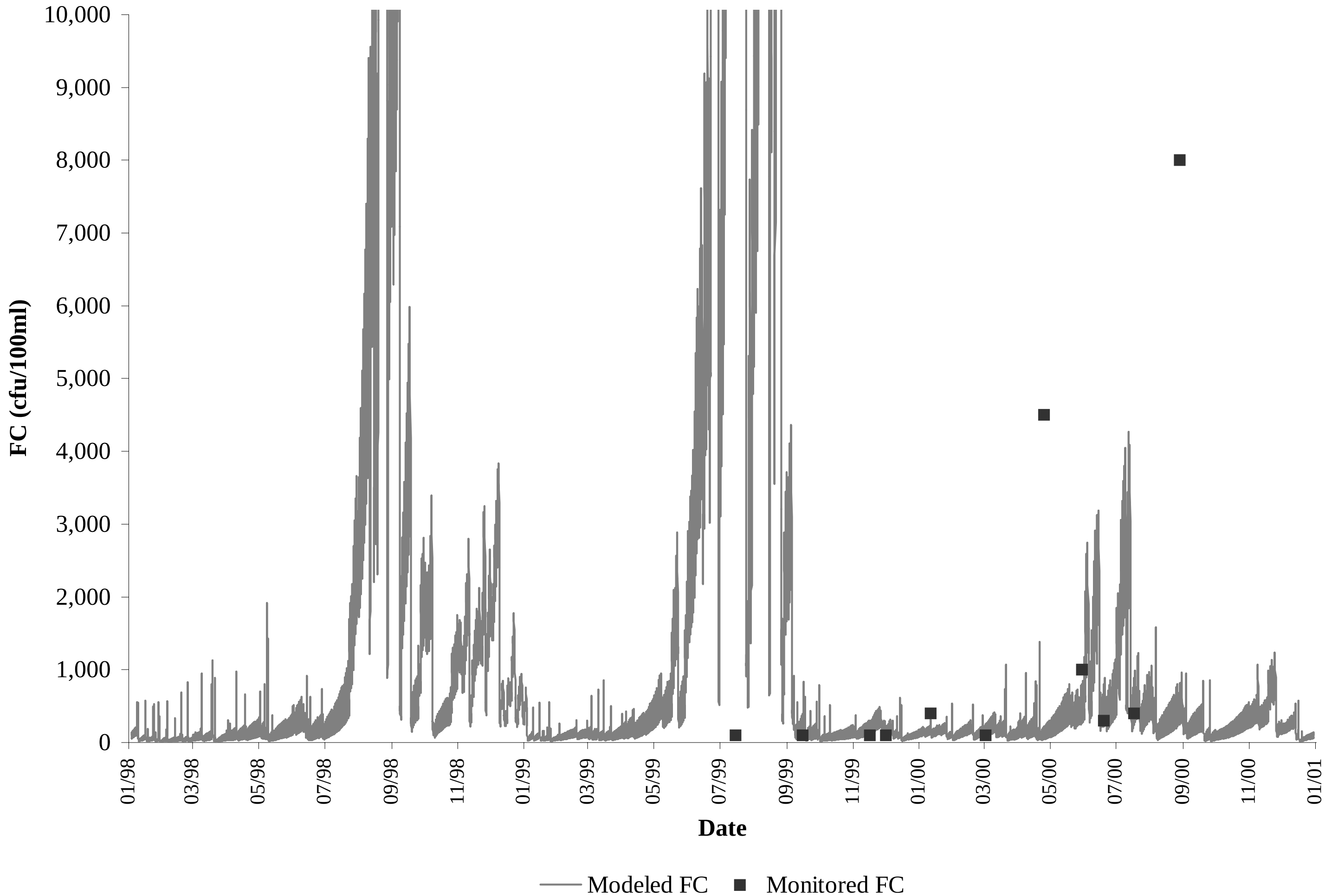

Figure 4.15 Quality validation for subwatershed 3 in Upper South Fork Catoctin Creek impairment.

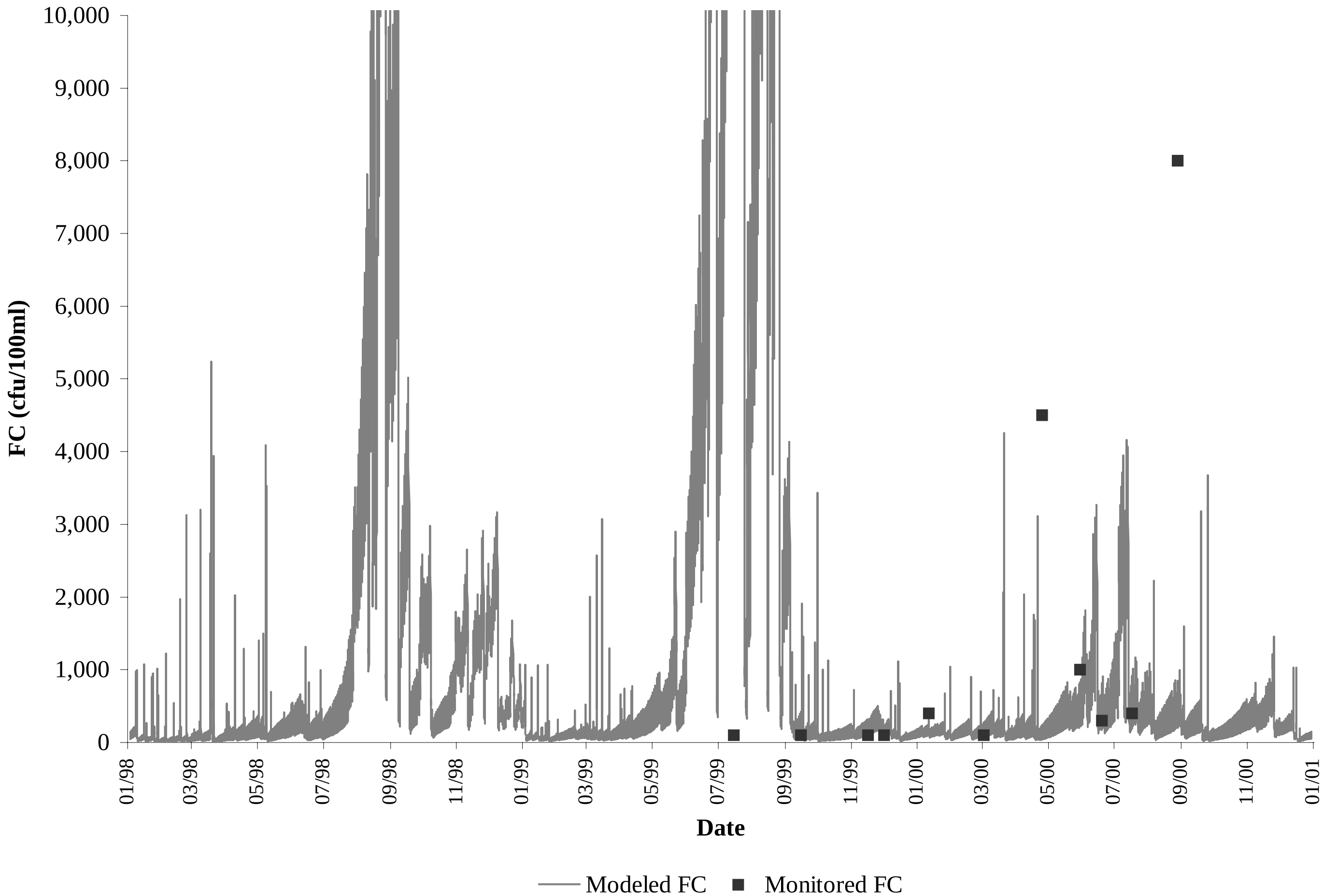

Figure 4.16 Quality validation for subwatershed 4 in Upper South Fork Catoctin Creek impairment.

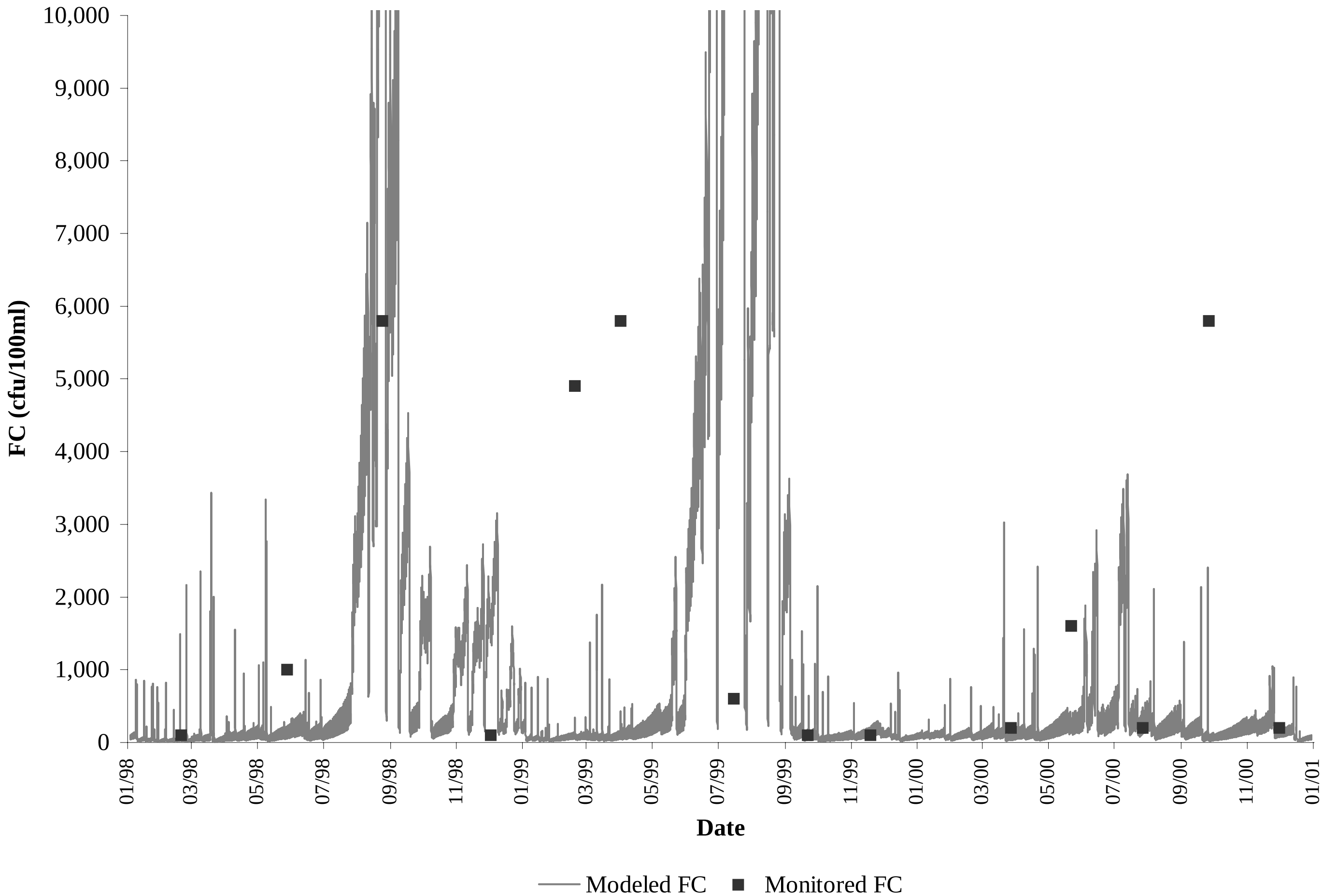

Figure 4.17 Quality validation for subwatershed 5 in Lower South Fork Catoctin Creek impairment.

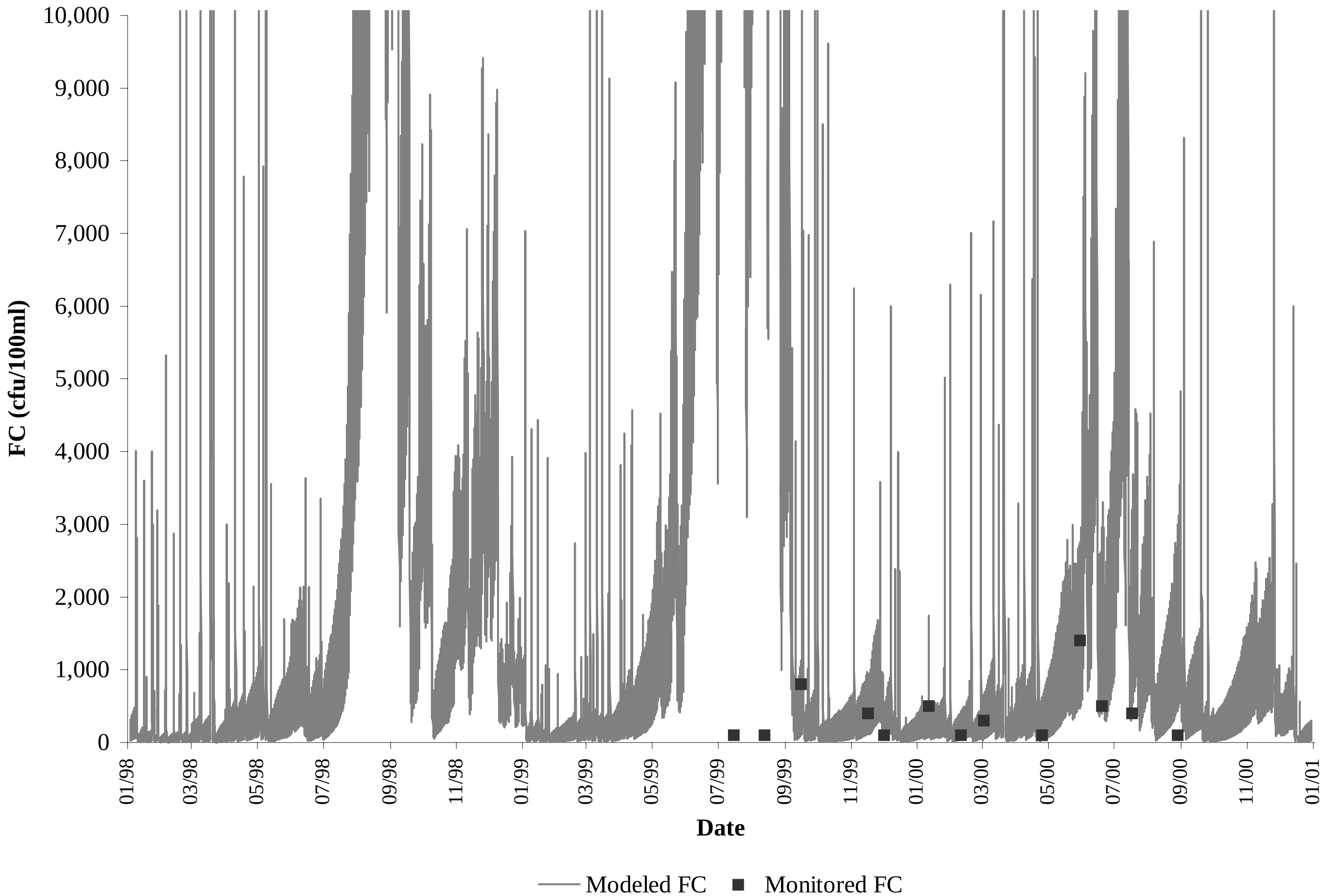

Figure 4.18 Quality validation for subwatershed 7 in North Fork Catoctin Creek impairment.

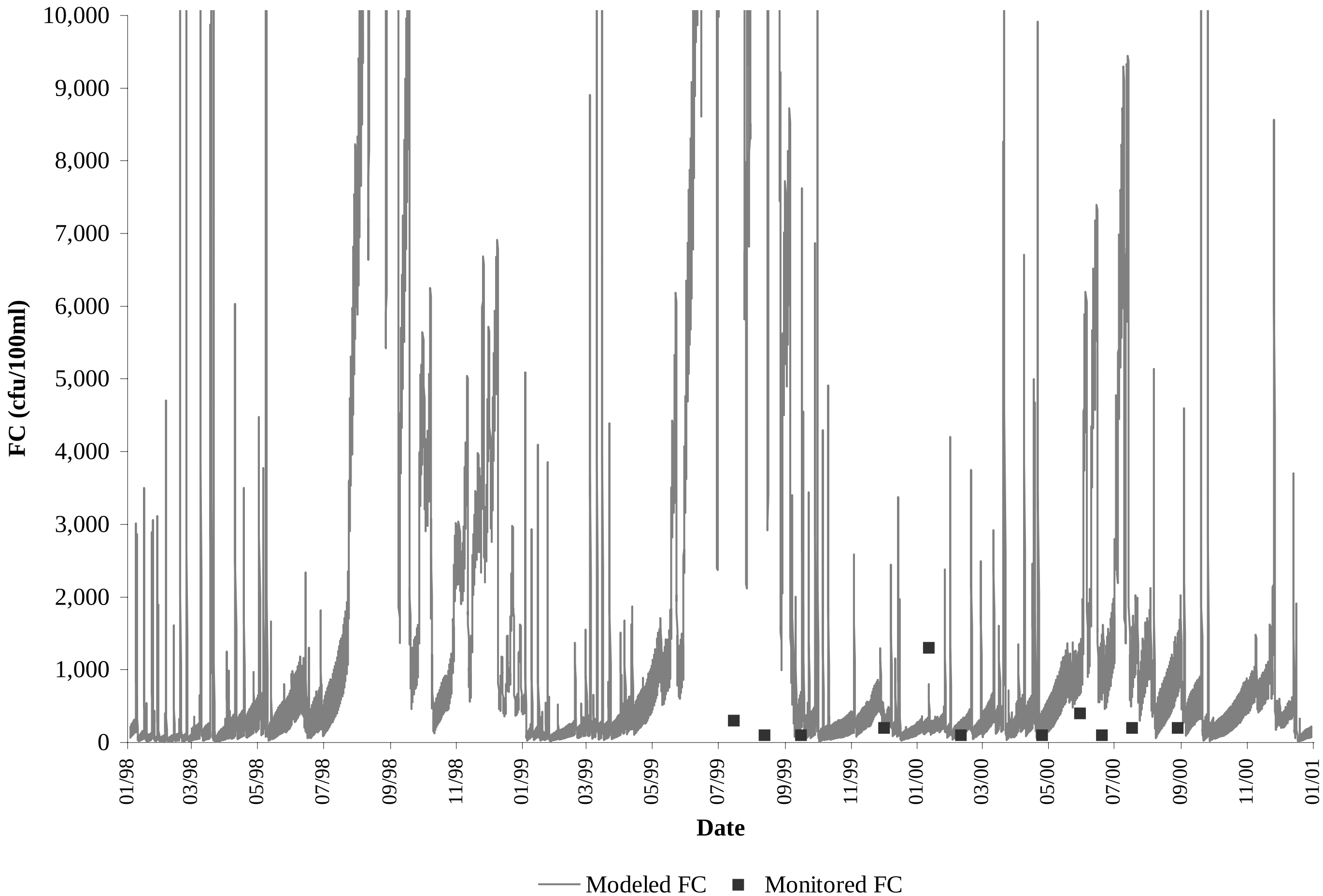

Figure 4.19 Quality validation for subwatershed 9 in North Fork Catoctin Creek impairment.

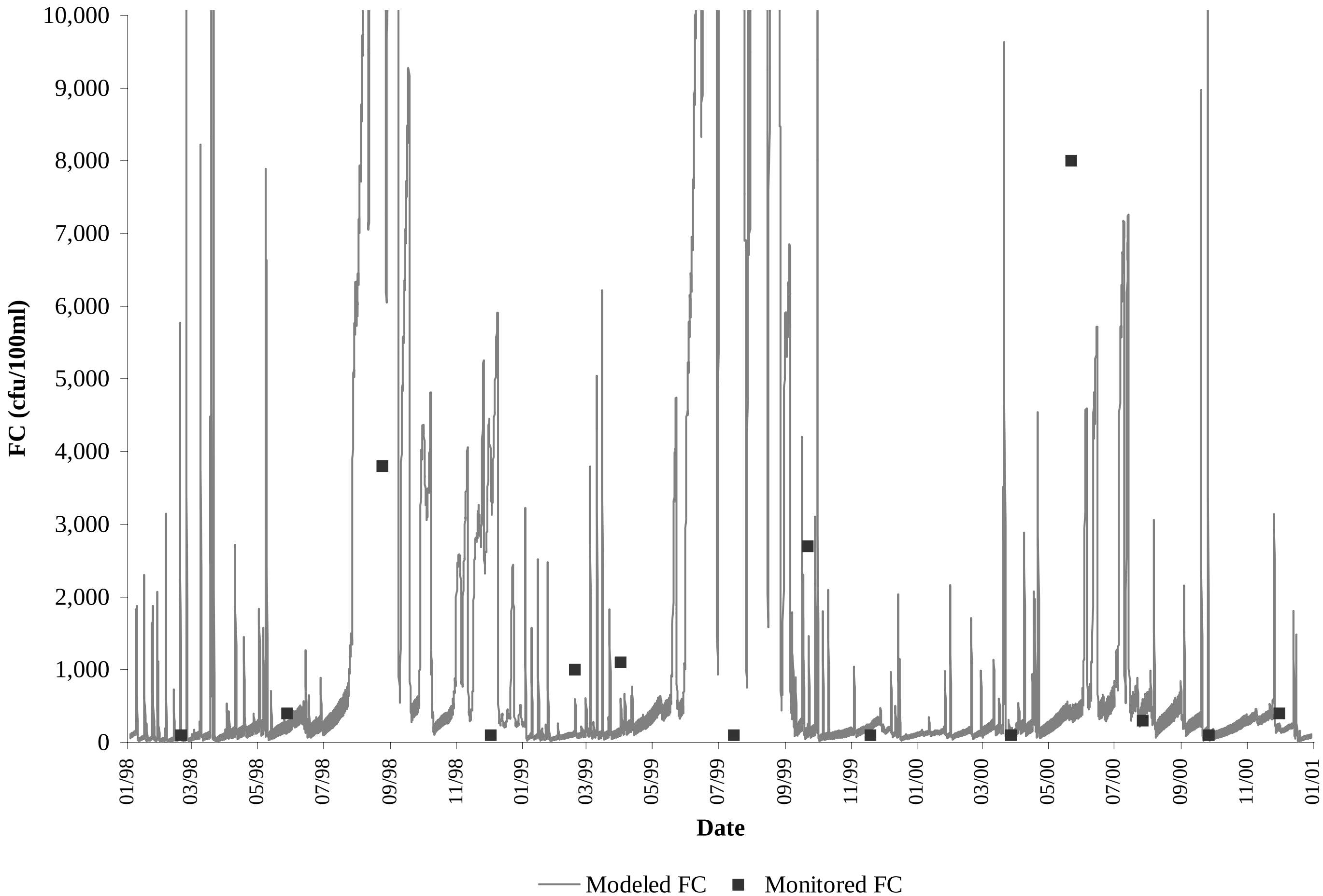

Figure 4.20 Quality validation for subwatershed 10 in North Fork Catoctin Creek impairment.

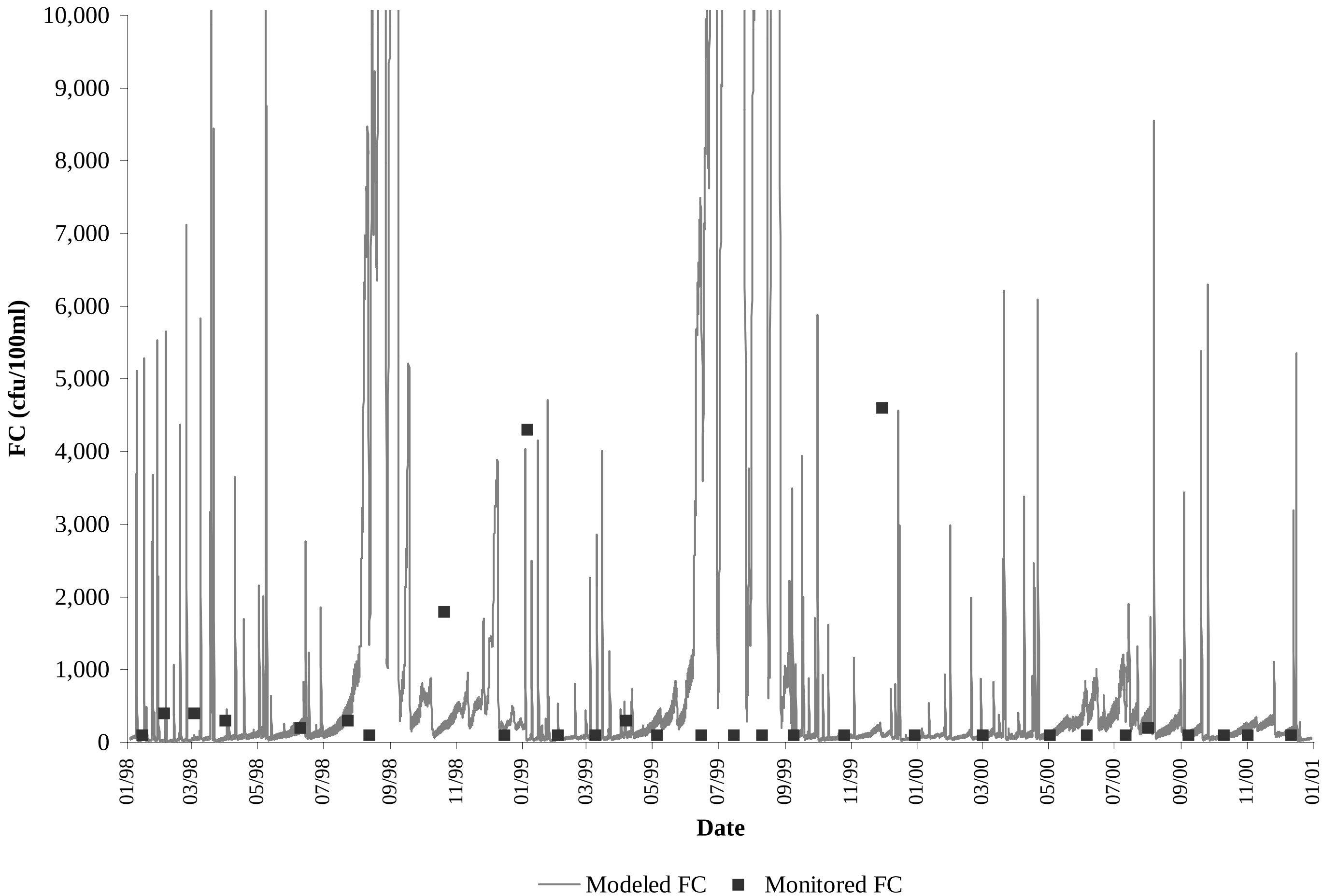

Figure 4.21 Quality validation for subwatershed 15 in Catoctin Creek impairment.

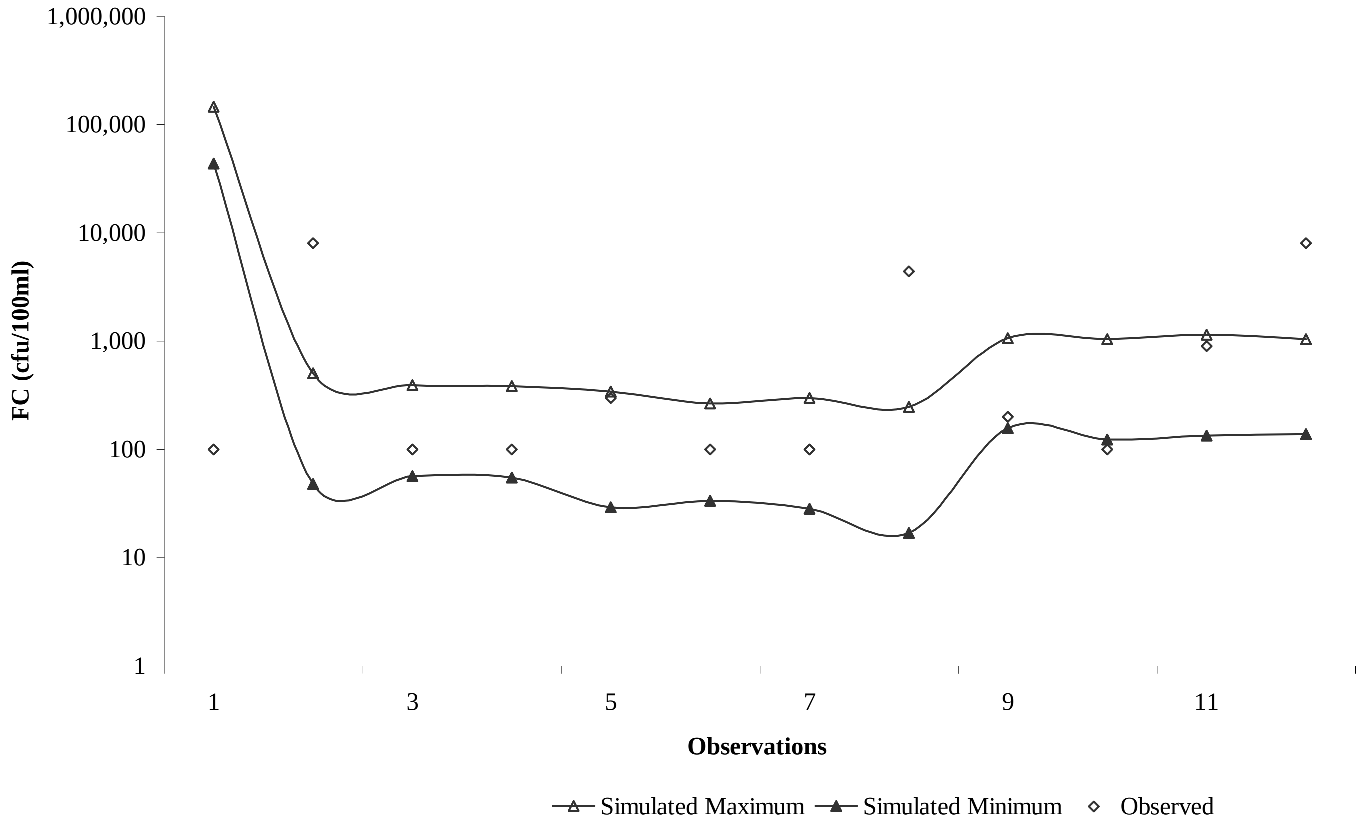

Figure 4.22 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 2 of the Upper South Fork Catoctin Creek impairment.

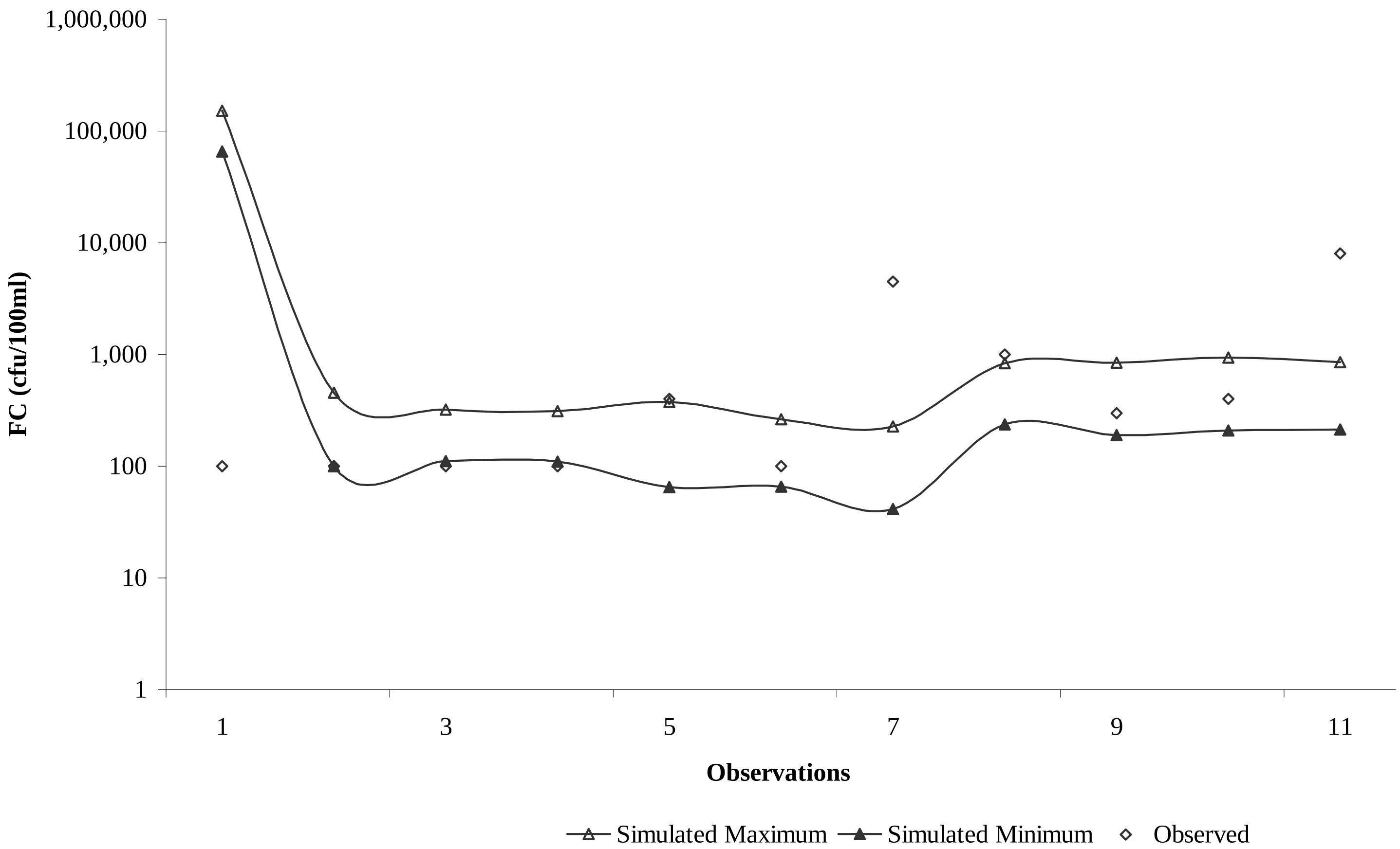

Figure 4.23 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 3 of the Upper South Fork Catoctin Creek impairment

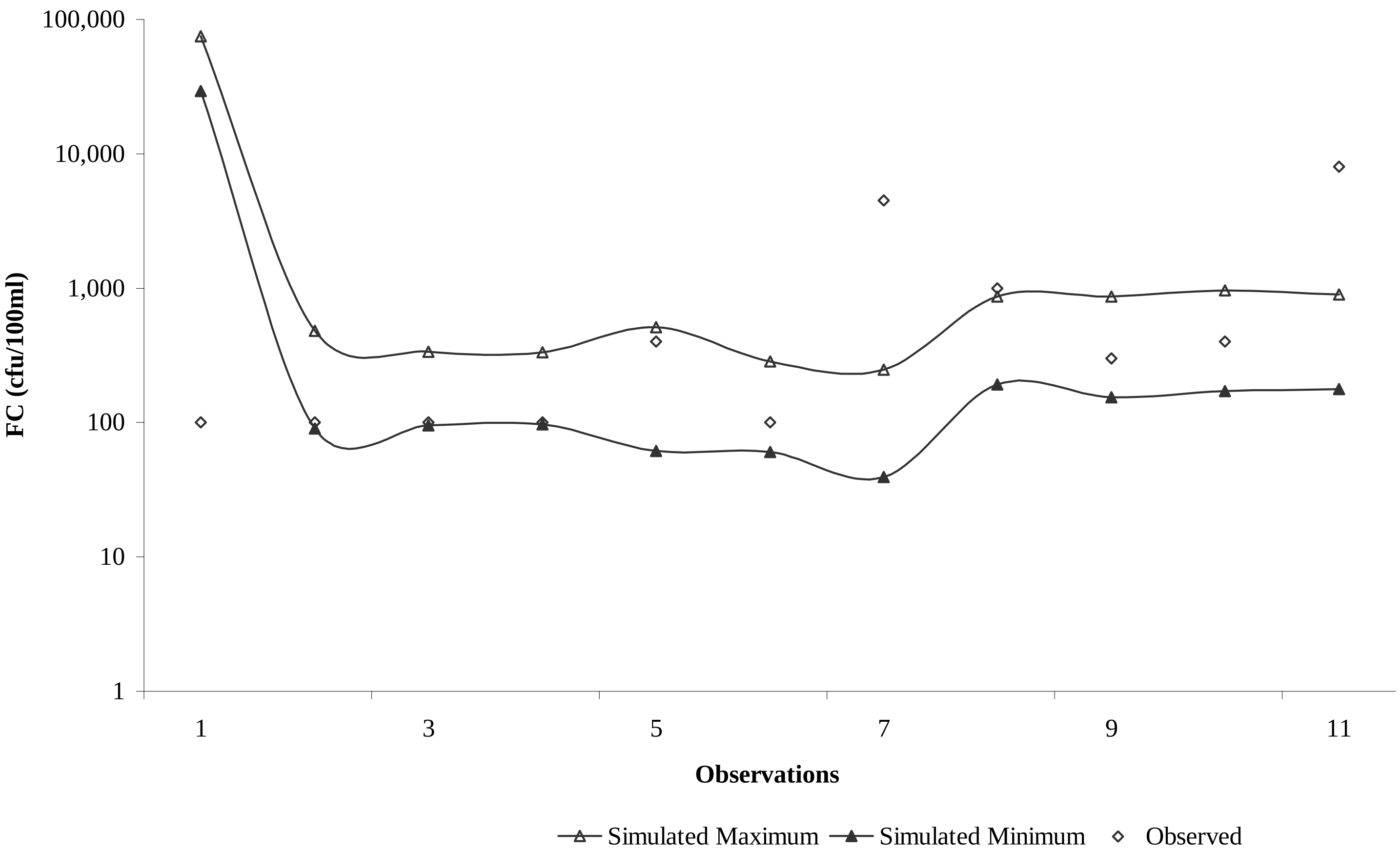

Figure 4.24 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 4 of the Upper South Fork Catoctin Creek impairment.

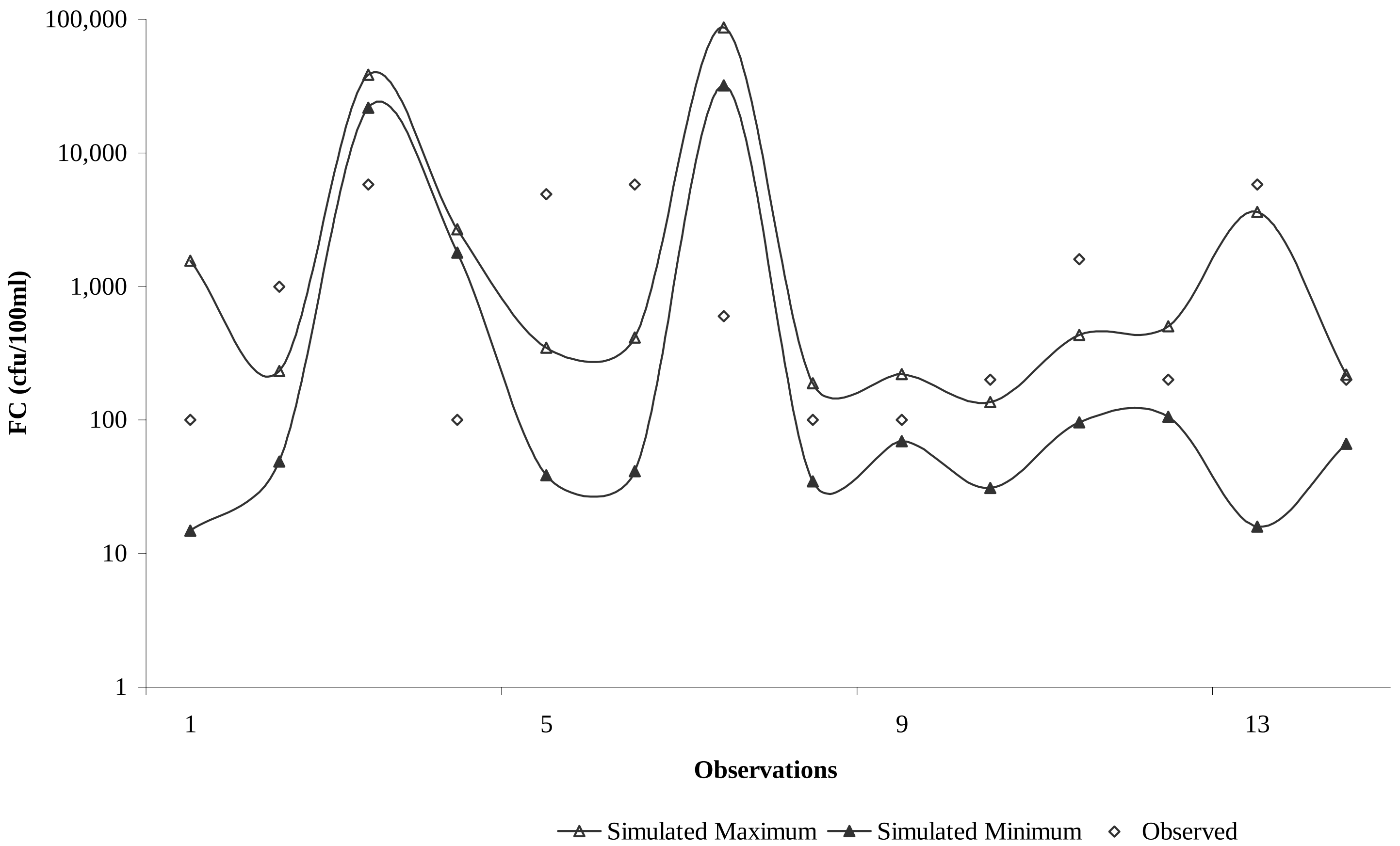

Figure 4.25 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 5 of the Lower South Fork Catoctin Creek impairment.

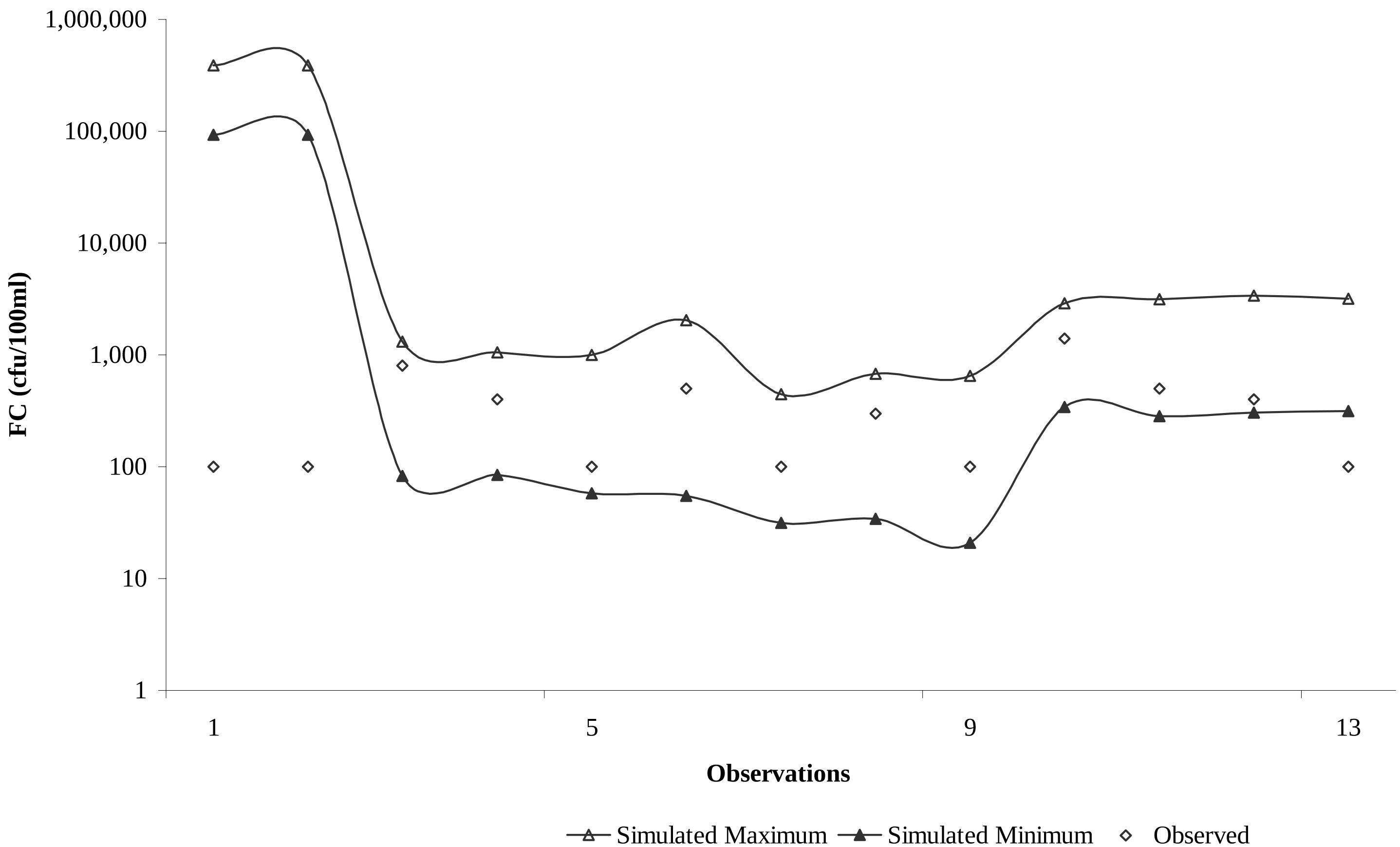

Figure 4.26 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 7 of the North Fork Catoctin Creek impairment.

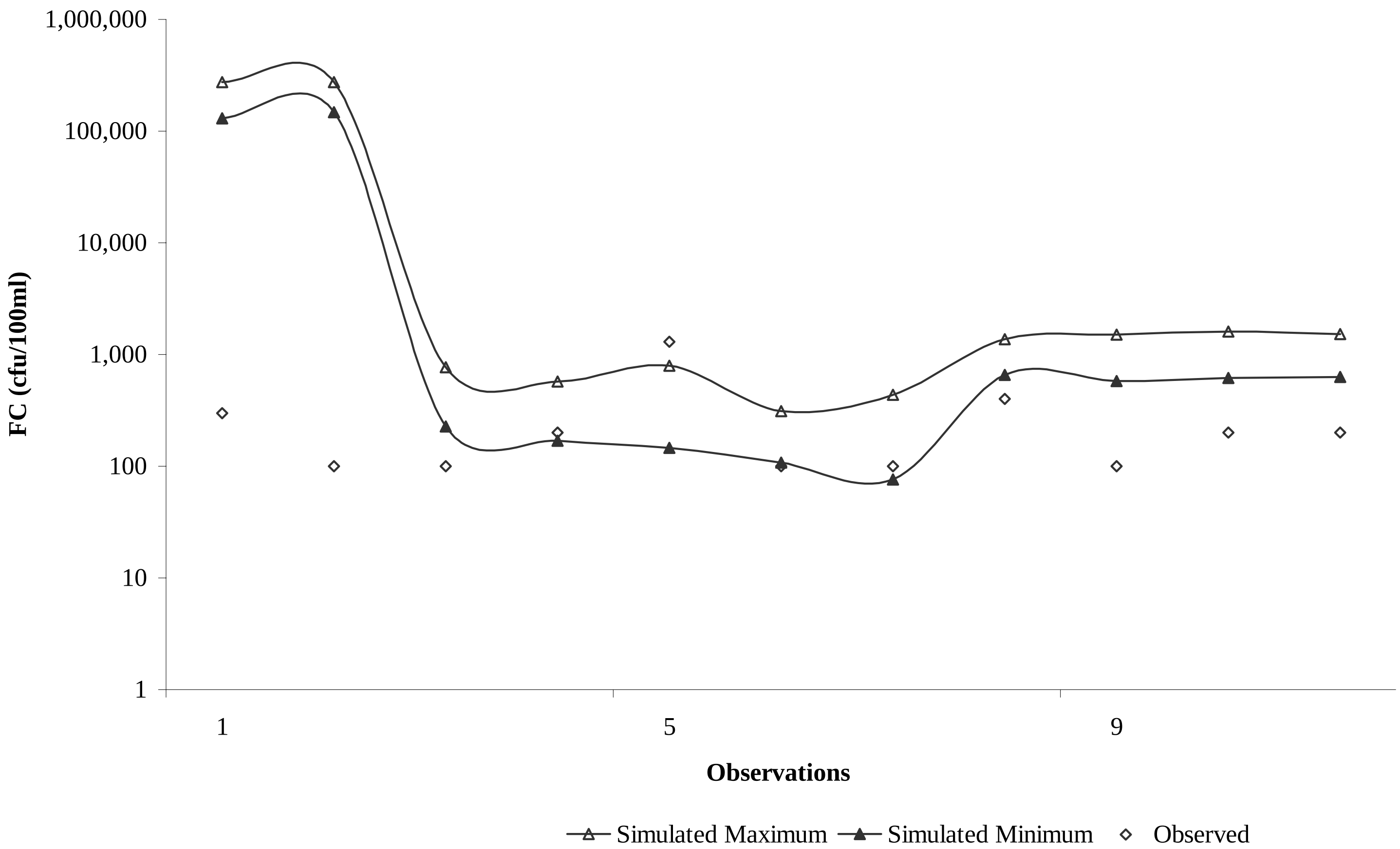

Figure 4.27 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 9 of the North Fork Catoctin Creek impairment.

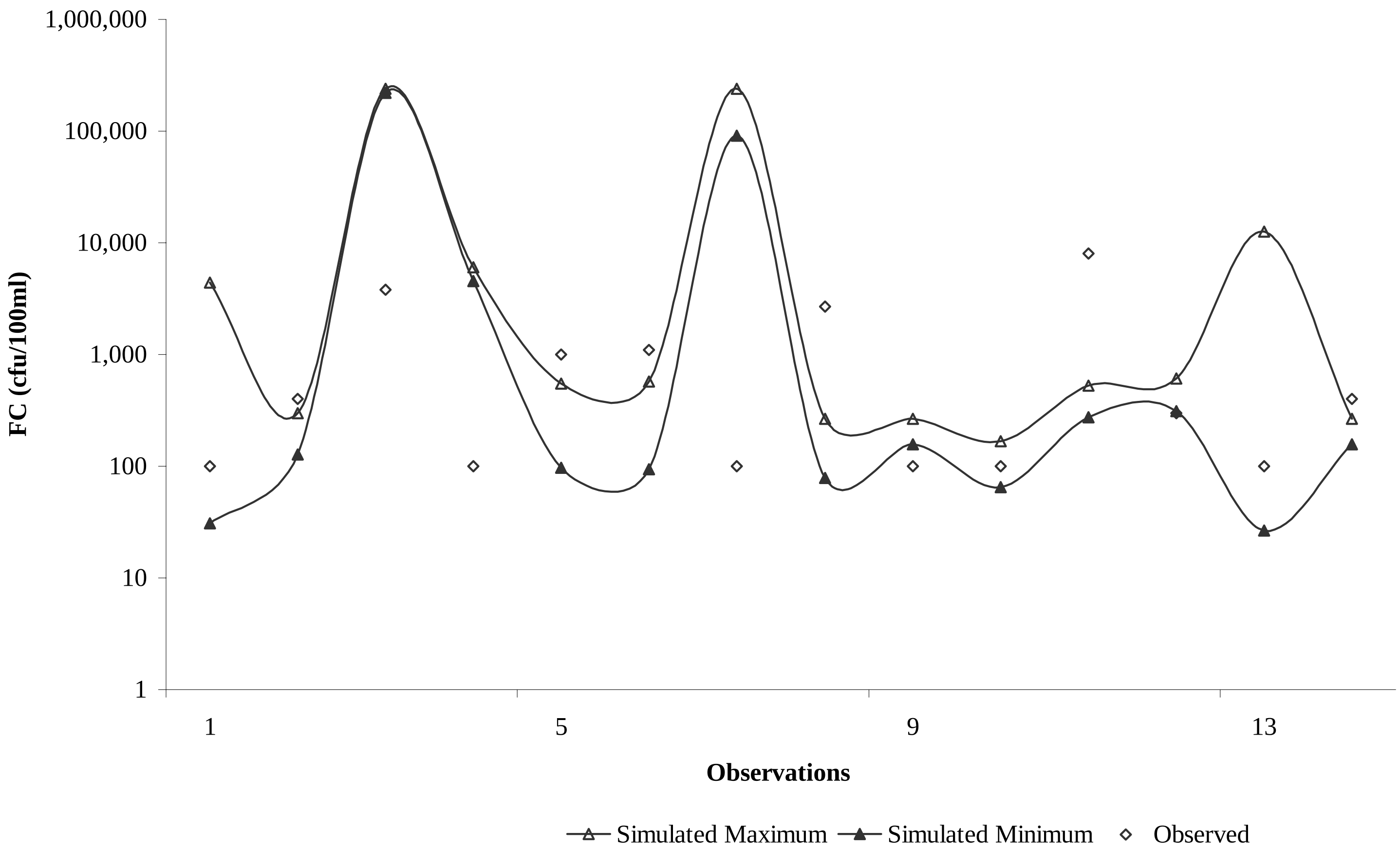

Figure 4.28 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 10 of the North Fork Catoctin Creek impairment.

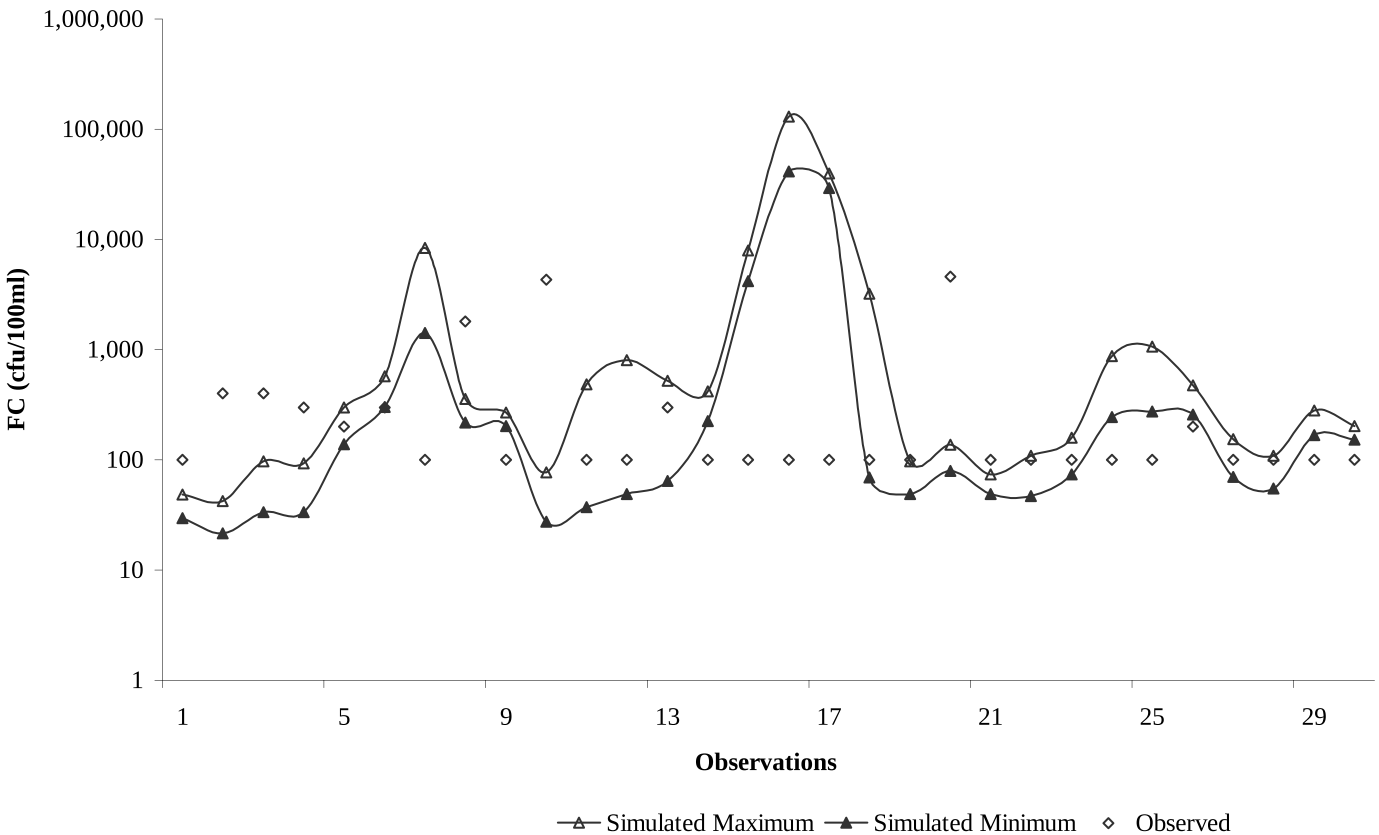

Figure 4.29 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 15 of the Catoctin Creek impairment.

4.7 Existing Loadings

All appropriate inputs were updated to 2001 conditions, as described in Section 4. All model runs were conducted using precipitation data for a representative period used for hydrologic calibration and validation (1/1/93 through 12/31/97). Figure 4.21 through Figure 4.24 show the 30-day geometric mean of fecal coliform concentrations in relation to the 200 cfu/100 ml standard. Appendix B contains tables with monthly loadings to the different land use areas in each subwatershed.

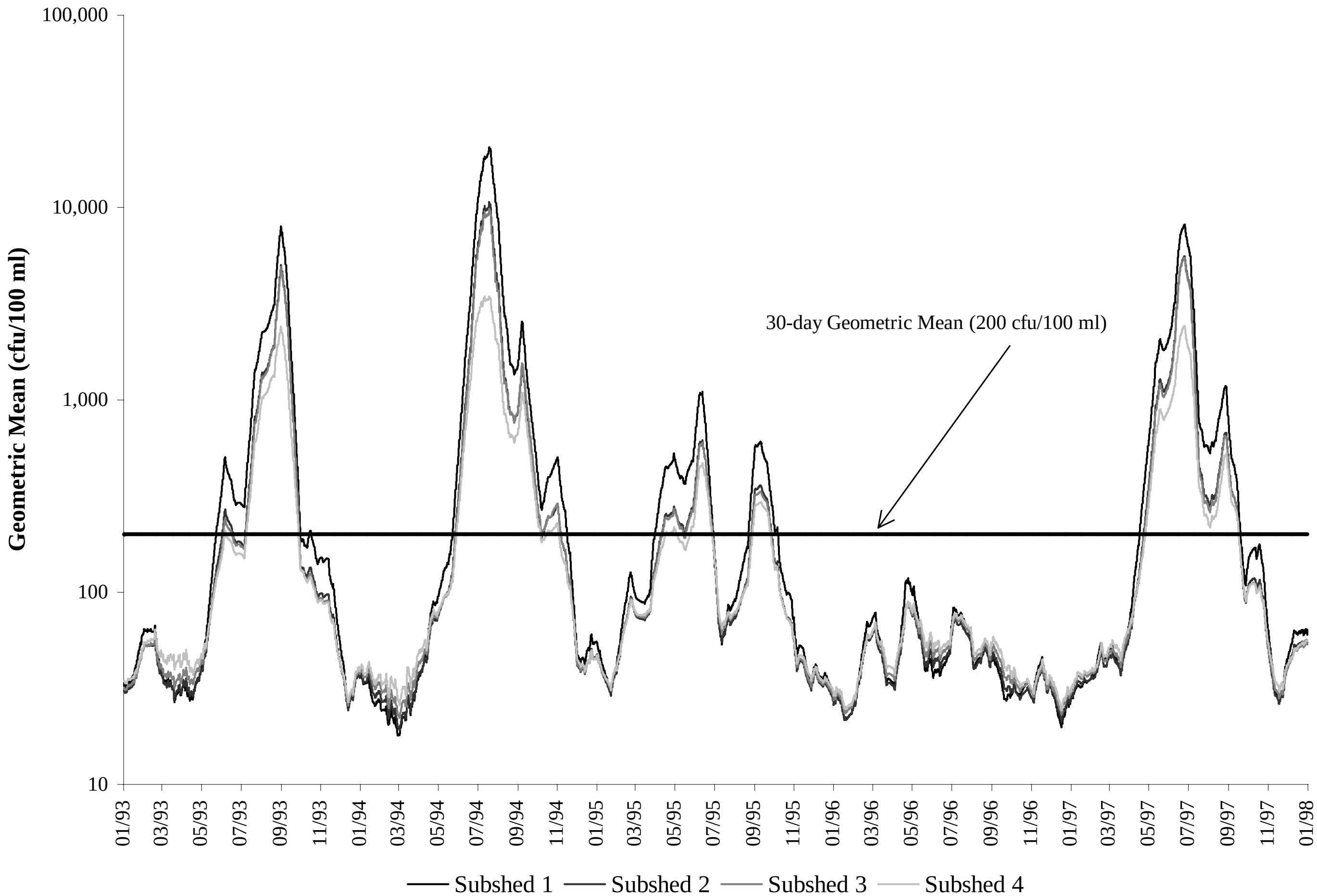

Figure 4.30 Existing conditions in subwatersheds 1-4 in Upper South Fork Catoctin Creek impairment.

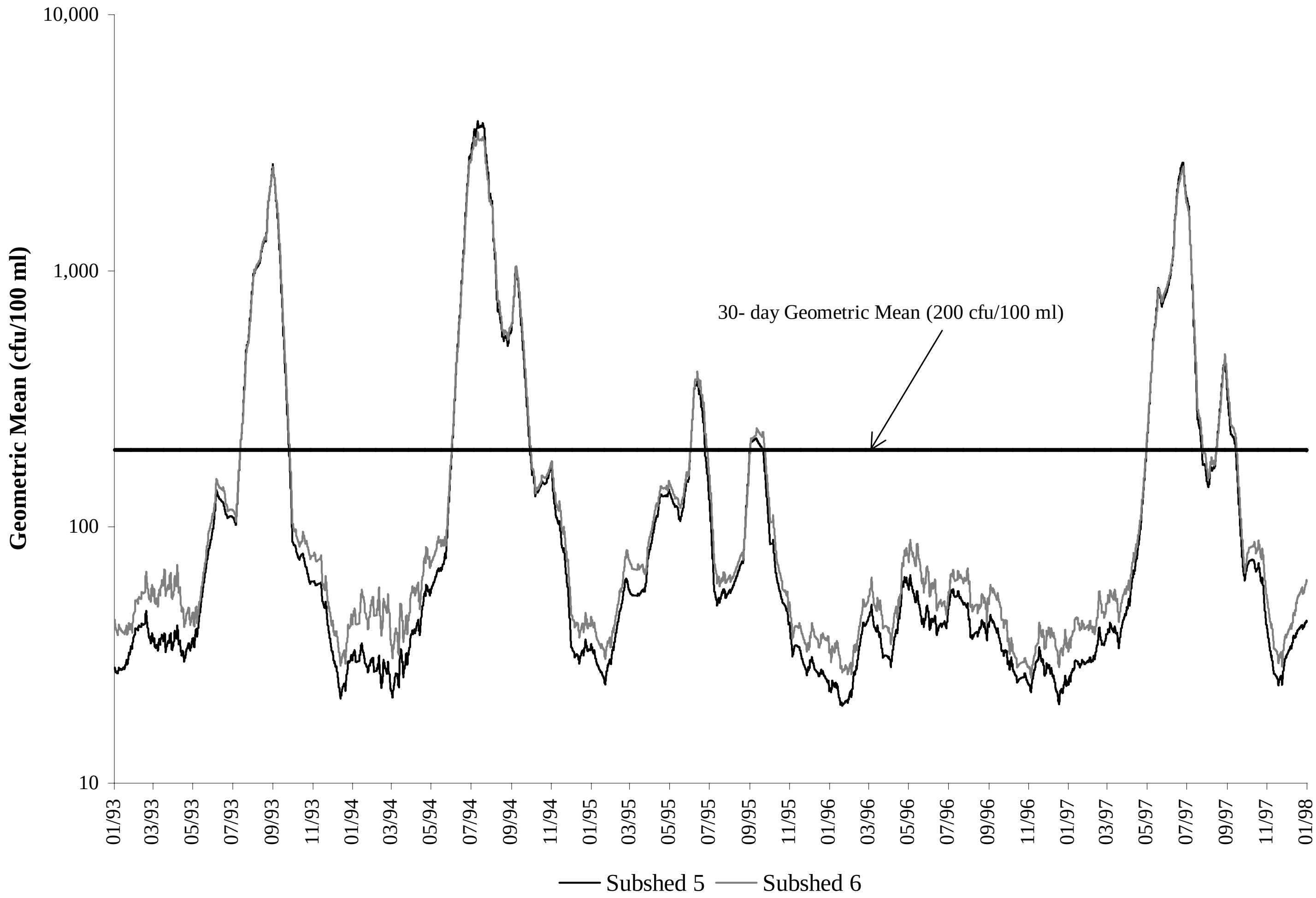

Figure 4.31 Existing conditions in subwatersheds 5-6 in Lower South Fork Catoctin Creek impairment.

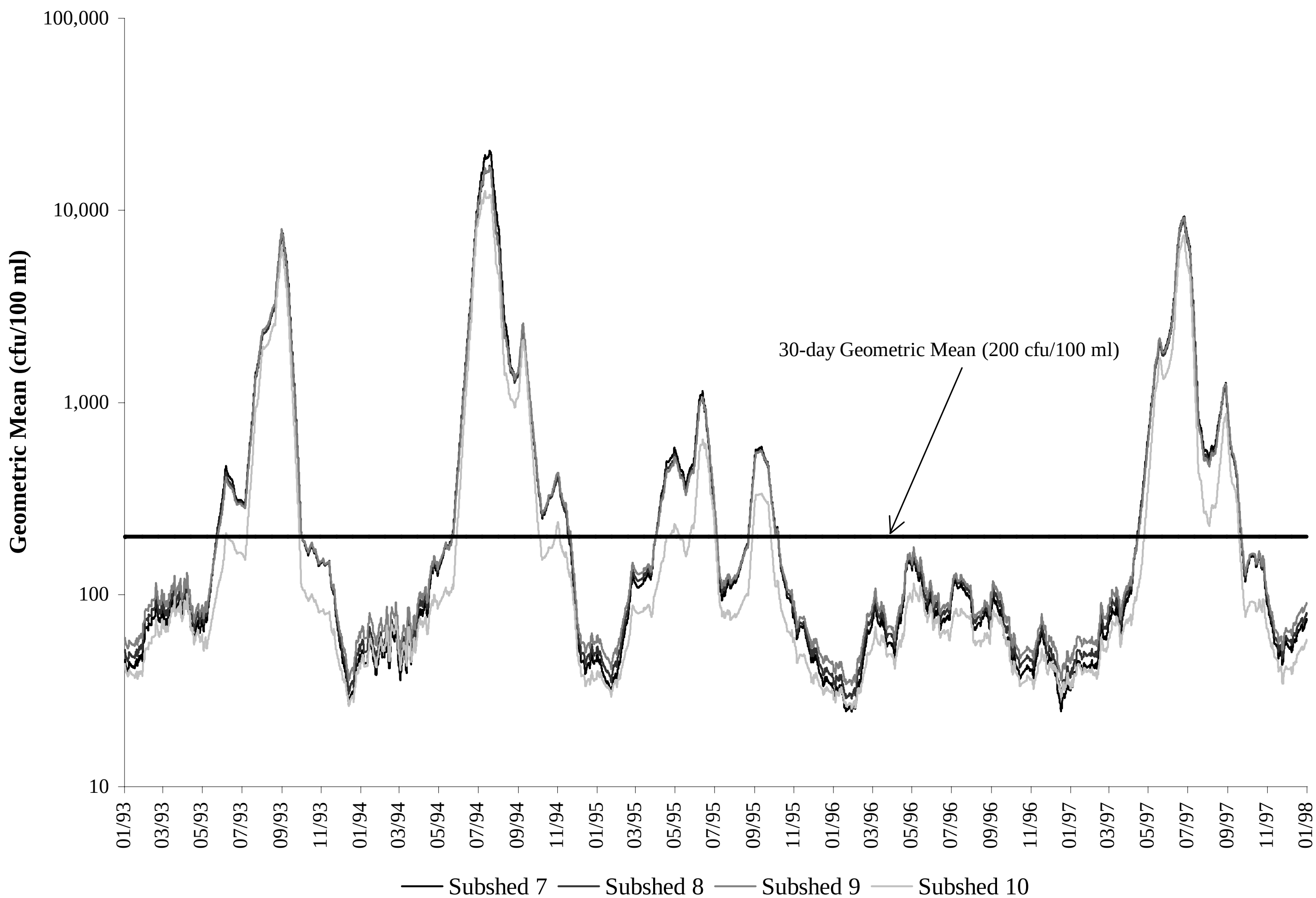

Figure 4.32 Existing conditions in subwatersheds 7-10 in North Fork Catoctin Creek impairment.

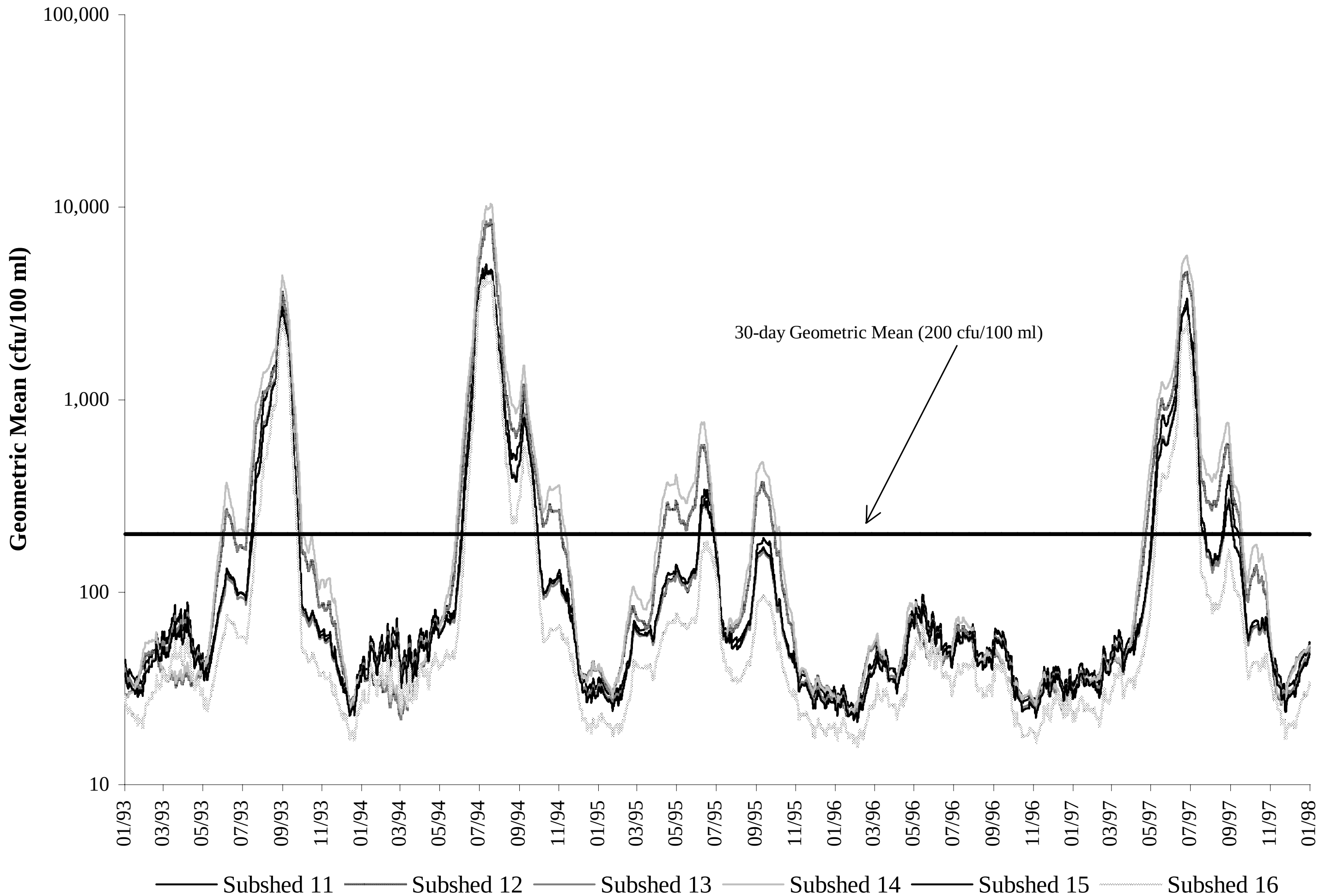

Figure 4.33 Existing conditions in subwatersheds 11-16 of Catoctin Creek impairment.

5. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (e.g. accuracy of wildlife populations). The definition is typically denoted by the expression:

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For fecal coliform bacteria, TMDL is expressed in terms of colony forming units (or resulting concentration). A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

5.1 Sensitivity Analysis

Sensitivity analyses were conducted first, to assess the sensitivity of the model to changes in hydrologic and water quality parameters then, to assess the impact of unknown variability in source allocation (e.g. seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads). Additional analyses were performed to define the sensitivity of the modeled system to growth or technology changes that impact waste production rates.

Sensitivity analyses were run on both hydrologic and water quality parameters. The parameters adjusted for the hydrologic sensitivity analysis are presented in Table 5.1, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1991-1995. Where an increase of 50% exceeded the maximum value for the parameter, the maximum value was used and the parameters increased over the base value was reported. The response of pertinent hydrologic outputs was recorded, and is reported in Table 5.2.

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from calendar year 1993 through 1997 and model parameters established for 2001 conditions. The four parameters impacting the model's water quality response (Table 5.3) were increased and decreased by amounts that were consistent with the range of values for the parameter.

Since the water quality standard for fecal coliform bacteria is based on concentrations rather than loadings, it was considered necessary to analyze the effect of source changes on the 30-day geometric-mean fecal coliform concentration. A running, 30-day, geometric mean was calculated at each 15-minute time-step, and the maximum value for each month was recorded. Deviations from the base run are given in Table 5.4 and plotted by month in Figures 5.1 and 5.4.

In addition to analyzing the sensitivity of the model response to changes in model parameters, the response of the model to changes in land-based and direct loads was analyzed. The impacts of land-based and direct load changes on the annual load are presented in Figure 5.5, while impacts on the maximum monthly geometric mean are presented in Figures 5.6 and 5.7.

Table 5.1 Base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	12
INFILT	Soil Infiltration Capacity	in/hr	0.025-0.075
AGWR	Groundwater Recession Rate	---	0.95
BASETP	Base Flow Evapotranspiration	---	0.02-0.07
INTFW	Interflow Inflow	---	2
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.021-0.375
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.118-1.329
MON-MANNING	Monthly Manning's *n* for Overland Flow	---	0.048-0.576
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.189-0.960

Table 5.2 Sensitivity analysis results for hydrologic model parameters.

Model Parameter	Parameter Change (%)	Percent Change In: Total Annual Runoff	High Flows	Low Flows	Total Storm Volume	Interflow	Surface Flow	Summer Flow Volume	Winter Flow Volume	Summer Storm Volume
AGWR	-50	0.90	19.06	-71.34	13.37	-1.38	-1.65	6.18	1.83	72.34
AGWR	-10	0.44	6.27	-39.90	1.83	-0.55	-0.67	1.64	1.76	8.51
AGWR	2.63	-0.53	-3.34	27.36	-0.46	0.35	0.43	12.91	-3.08	12.77
AGWR	3.89	-1.49	-6.35	53.26	-1.28	0.63	0.74	37.09	-7.64	36.17
AGWR	4.42	-2.66	-8.23	66.29	-2.29	0.71	0.80	49.82	-10.65	48.94
AGWR	4.63	-3.72	-9.18	68.40	-3.02	0.71	0.80	52.73	-12.07	53.19
AGWR	4.84	-5.94	-10.37	63.84	-4.30	0.71	0.80	50.91	-14.01	51.06
AGWR	5.16	-22.48	-15.29	-8.47	-11.36	0.16	0.25	4.00	-24.42	8.51
BASETP	-50	0.61	-1.00	12.21	-0.73	-1.93	-2.21	7.64	-1.04	4.26
BASETP	-10	0.11	-0.19	2.12	-0.09	-0.39	-0.43	1.27	-0.17	2.13
BASETP	10	-0.10	0.16	-2.12	0.18	0.35	0.43	-1.27	0.17	0.00
BASETP	50	-0.51	0.84	-9.61	0.64	1.69	1.96	-5.45	0.86	-2.13
INFILT	-50	0.44	13.41	-24.59	12.64	-8.00	68.01	-7.82	4.39	4.26
INFILT	-30	0.19	6.54	-12.87	6.59	-2.40	32.84	-4.55	2.32	2.13
INFILT	-10	0.04	1.85	-3.91	2.01	-0.24	9.07	-1.45	0.69	0.00
INFILT	10	-0.03	-1.66	3.42	-1.74	-0.24	-7.66	1.27	-0.59	0.00
INFILT	30	-0.07	-4.48	9.77	-5.04	-1.50	-19.85	3.82	-1.63	0.00
INFILT	50	-0.09	-6.79	15.31	-7.78	-3.39	-29.04	6.18	-2.42	0.00
INTFW	-50	-0.66	2.47	3.26	3.94	-49.27	55.94	-1.27	-0.38	-4.26
INTFW	-10	-0.09	0.22	0.49	0.64	-7.13	8.09	-0.18	-0.03	0.00
INTFW	10	0.09	-0.16	-0.65	-0.55	6.14	-6.99	0.18	0.07	2.13
INTFW	50	0.34	-0.54	-2.44	-2.66	23.95	-26.96	0.91	0.28	4.26
LZSN	-50	8.28	12.33	-5.86	9.07	11.22	24.33	-1.27	12.00	4.26
LZSN	-30	4.99	6.08	-0.33	4.49	5.63	10.54	-0.55	6.64	2.13
LZSN	-10	1.67	1.76	0.81	1.37	1.61	2.76	0.00	2.14	0.00
LZSN	10	-1.64	-1.68	-1.30	-1.28	-1.61	-2.45	-0.18	-2.14	0.00
LZSN	30	-4.95	-4.75	-5.37	-3.66	-4.77	-6.74	-0.73	-6.30	0.00
LZSN	50	-8.20	-7.55	-10.42	-6.14	-7.88	-10.60	-1.82	-10.13	-2.13
MON-INTERCEP	-50	1.23	-0.54	10.75	-0.09	3.35	-1.35	13.64	-1.56	12.77
MON-INTERCEP	-10	0.23	-0.14	1.95	0.00	0.51	-0.25	2.55	-0.28	2.13
MON-INTERCEP	10	-0.21	0.11	-2.12	0.09	-0.47	0.31	-2.36	0.24	-2.13
MON-INTERCEP	50	-0.99	0.52	-8.96	0.18	-1.89	1.04	-10.18	1.14	-8.51
MON-LZETP	-50	12.56	9.61	19.87	9.98	11.58	18.32	23.09	11.80	21.28
MON-LZETP	-30	5.98	4.10	11.24	4.49	5.12	7.48	11.45	5.43	8.51
MON-LZETP	-10	1.00	0.62	1.95	0.73	0.83	1.16	2.00	0.90	2.13
MON-LZETP	10	-0.74	-0.49	-1.63	-0.55	-0.67	-0.86	-1.45	-0.69	0.00
MON-LZETP	30	-1.69	-1.09	-3.58	-1.19	-1.50	-1.84	-3.09	-1.63	-2.13
MON-LZETP	50	-2.30	-1.44	-5.05	-1.56	-2.01	-2.45	-4.36	-2.18	-2.13
MON-MANNING	-50	0.23	2.77	-2.12	2.84	-9.49	22.37	0.55	0.38	2.13
MON-MANNING	-10	0.04	0.41	-0.33	0.55	-1.38	3.19	0.00	0.03	0.00
MON-MANNING	10	-0.03	-0.38	0.16	-0.46	1.18	-2.82	0.00	0.00	0.00
MON-MANNING	50	-0.11	-1.44	0.98	-1.92	4.69	-11.21	-0.18	-0.07	-10.64
MON-UZSN	-50	3.85	10.24	-9.77	10.07	23.12	15.26	20.91	0.10	40.43
MON-UZSN	-30	1.96	5.51	-4.56	5.22	11.66	8.21	9.64	0.21	12.77
MON-UZSN	-10	0.59	1.63	-1.30	1.56	3.35	2.45	2.55	0.10	2.13
MON-UZSN	10	-0.51	-1.47	0.98	-1.47	-2.99	-2.27	-2.18	-0.10	0.00
MON-UZSN	30	-1.43	-4.05	2.28	-4.03	-8.03	-6.31	-5.45	-0.28	-2.13
MON-UZSN	50	-2.22	-6.30	3.42	-6.41	-12.25	-9.87	-8.00	-0.48	-4.26

Table 5.3 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	42E+6 to 1E+12
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	1.0
MON-IFLW-CONC	FC Interflow Concentration	FC/ft^3	6 to 1,600
FSTDEC	In-stream First Order Decay Rate	1/day	0.20 to 5.35

Table 5.4 Percent Change in average monthly FC geometric mean for the years 1993-1997.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly FC Geometric Mean for the Years 1993-1997											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	94.47	99.20	99.76	105.92	98.28	66.51	59.13	69.00	72.61	102.65	104.40	96.92
FSTDEC	-10	12.38	12.86	12.92	13.29	12.08	8.63	8.07	8.95	9.48	12.70	13.11	12.74
FSTDEC	10	-10.46	-10.88	-10.94	-11.15	-10.16	-7.36	-6.98	-7.63	-8.09	-10.65	-11.01	-10.66
FSTDEC	50	-39.62	-40.55	-40.77	-41.18	-37.65	-27.87	-26.92	-28.87	-30.66	-39.32	-40.61	-39.82
MON-IFLW CONC	-100	-0.52	-0.29	-0.24	-0.12	-0.09	-0.07	-0.08	-0.08	-0.05	-0.06	-0.30	-0.49
MON-IFLW CONC	-50	-0.25	-0.14	-0.10	-0.05	-0.04	-0.04	-0.04	-0.04	-0.02	-0.03	-0.15	-0.22
MON-IFLW CONC	50	0.28	0.15	0.13	0.07	0.04	0.04	0.04	0.04	0.02	0.04	0.16	0.32
MON-IFLW CONC	100	0.52	0.30	0.24	0.13	0.08	0.08	0.07	0.08	0.05	0.06	0.30	0.61
SQOLIM	-50	-11.69	-11.56	-11.34	-10.33	-4.89	-4.77	-4.28	-3.68	-4.49	-4.23	-6.48	-10.57
SQOLIM	-25	-5.01	-4.97	-5.12	-4.76	-2.53	-2.21	-1.97	-1.72	-2.10	-2.08	-3.18	-5.16
SQOLIM	50	10.78	8.23	8.88	9.17	5.00	4.28	2.95	2.56	3.41	4.23	5.51	9.80
SQOLIM	100	18.94	16.79	15.87	12.47	6.84	6.24	5.48	4.42	5.74	8.06	9.88	17.04
WSQOP	-50	18.06	16.17	16.69	13.89	7.10	5.51	5.62	4.67	5.82	7.12	7.81	15.69
WSQOP	-10	2.43	2.17	2.07	1.86	0.95	0.75	0.69	0.62	0.80	0.87	1.08	2.13
WSQOP	10	-1.83	-1.81	-1.79	-1.61	-0.82	-0.66	-0.61	-0.55	-0.69	-0.68	-0.93	-1.63
WSQOP	50	-7.21	-7.18	-7.16	-6.42	-3.04	-2.68	-2.49	-2.19	-2.75	-2.48	-3.73	-6.40

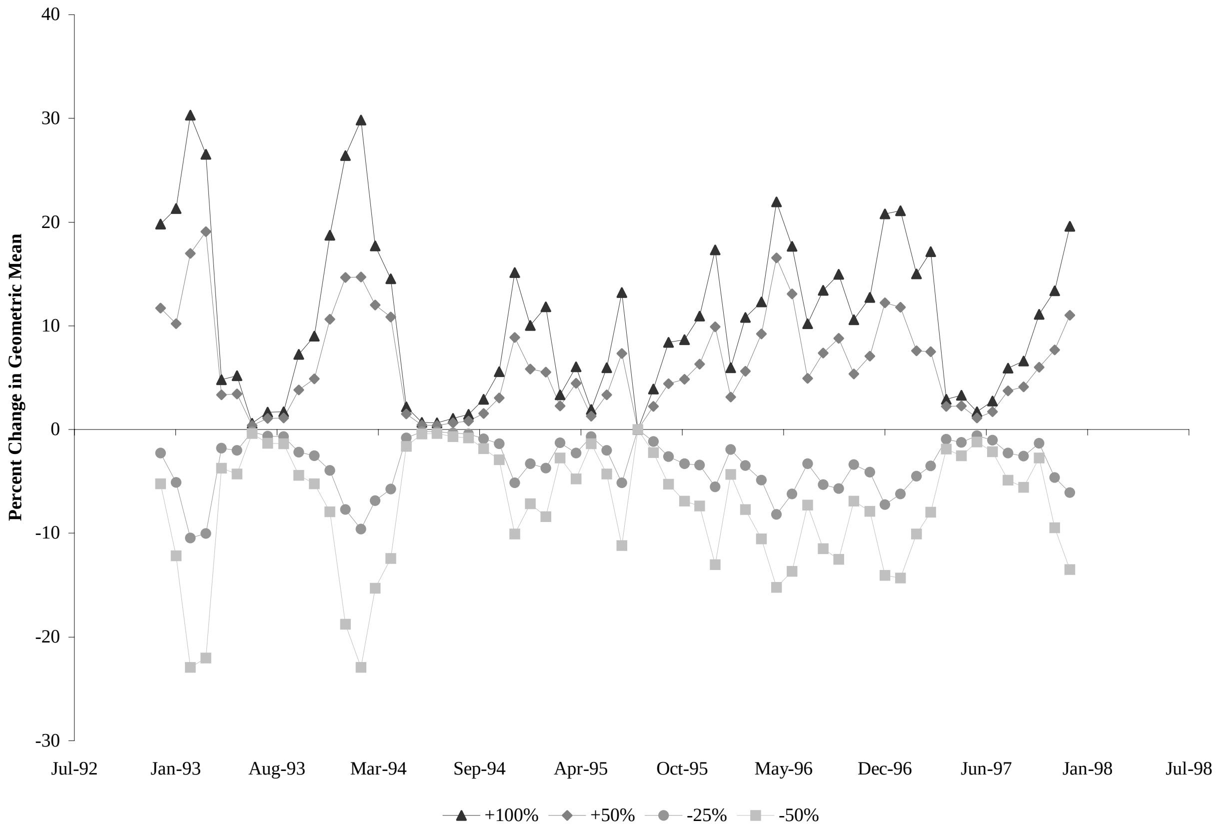

Figure 5.1 **Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in maximum FC accumulation on land (MON-SQOLIM).**

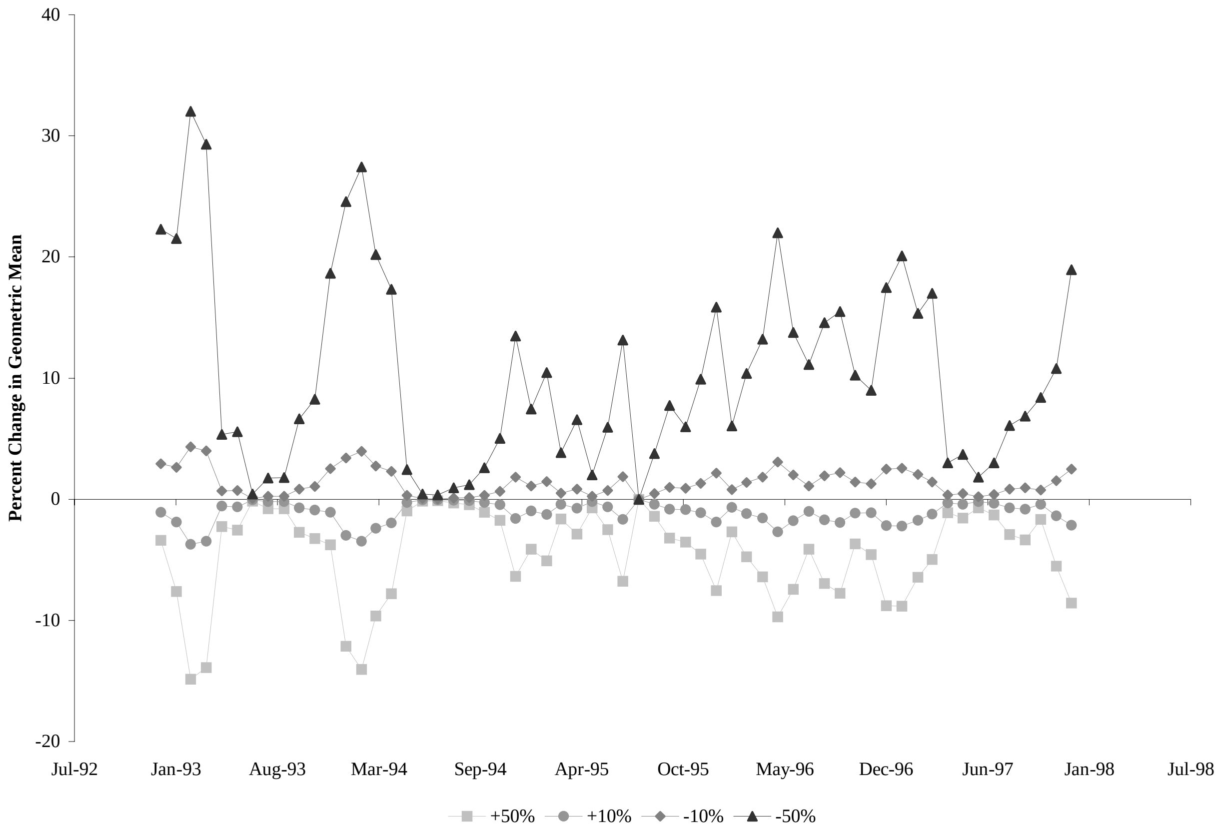

Figure 5.2 Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in the wash-off rate for FC on land surfaces (WSQOP).

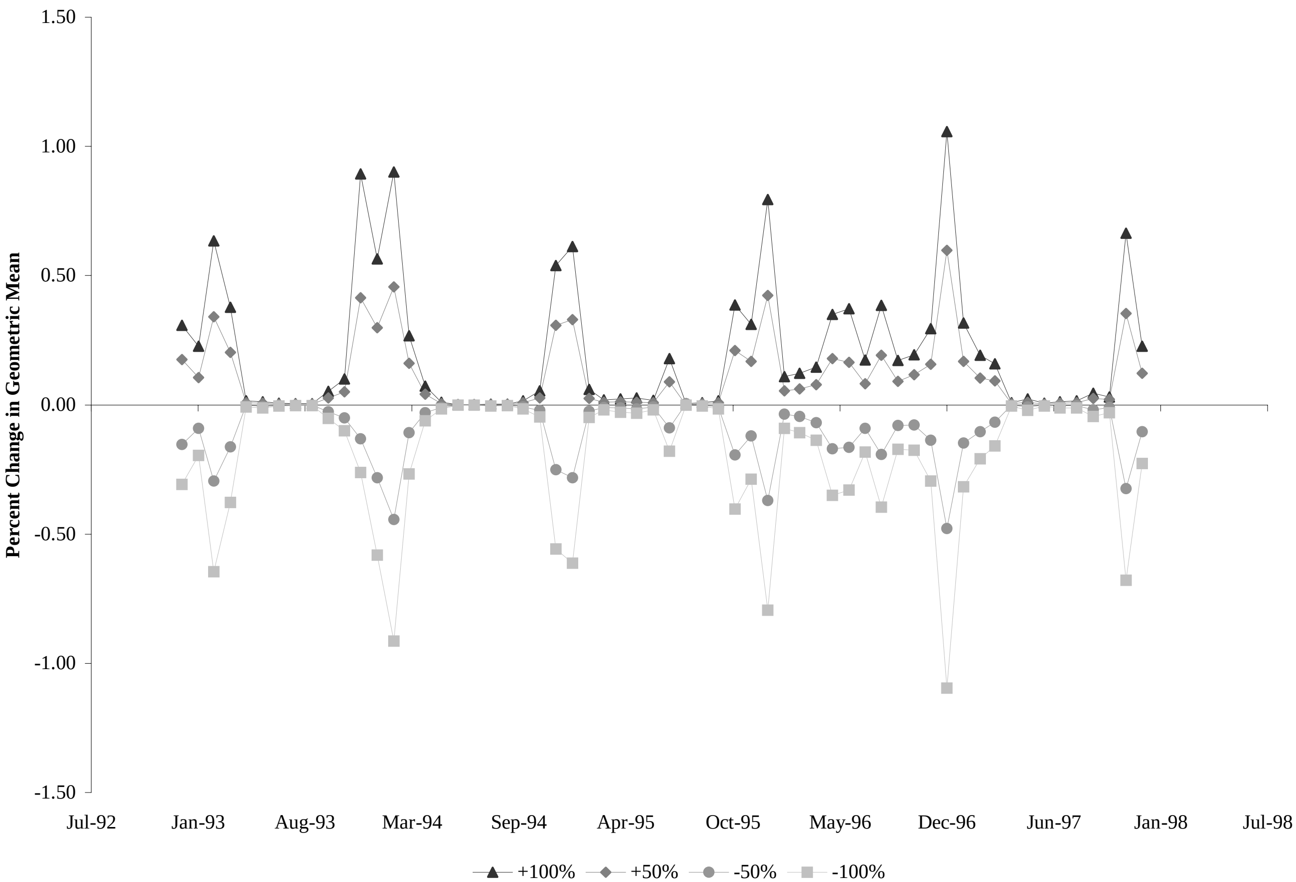

Figure 5.3 **Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in the concentration of fecal coliform in interflow (MON-IFLW-CONC).**

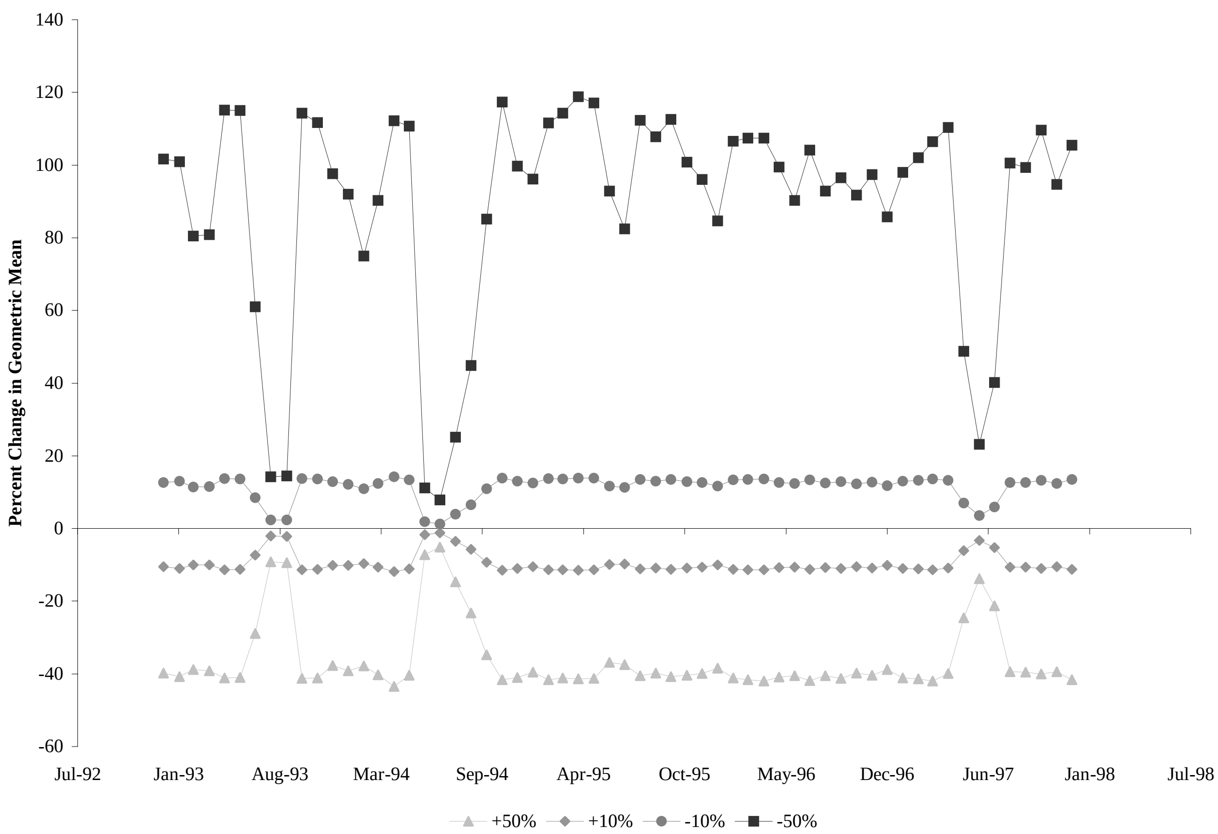

Figure 5.4 Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in the in-stream first-order decay rate (FSTDEC).

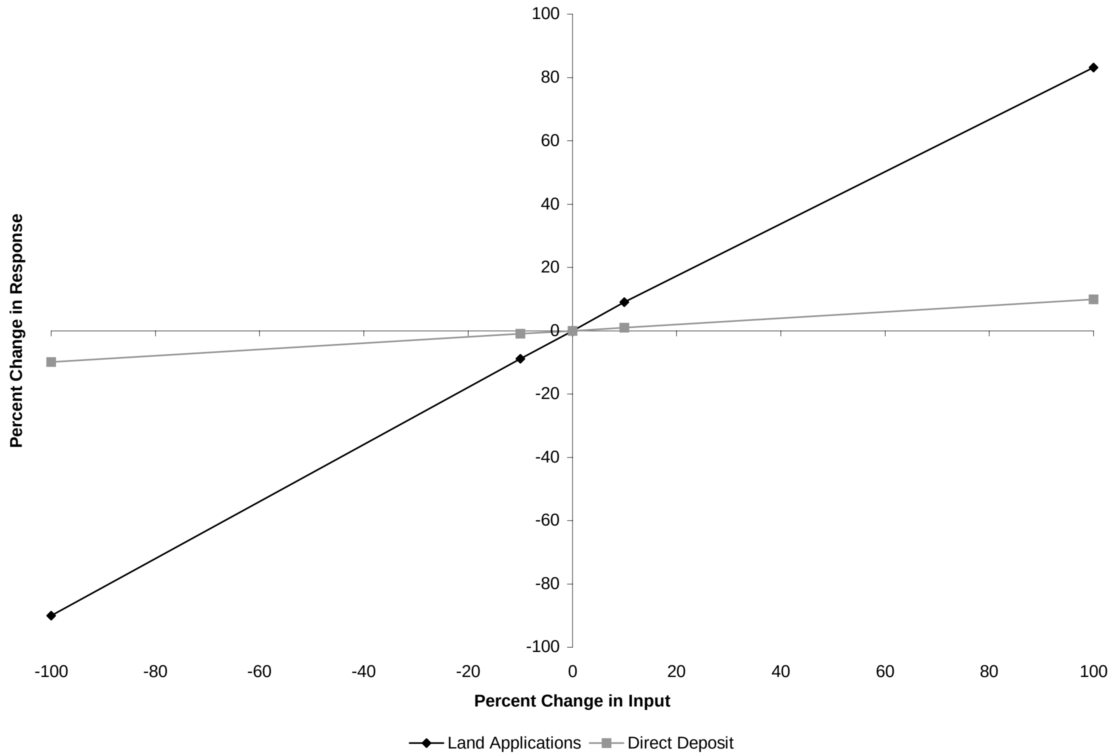

Figure 5.5 Results of total loading sensitivity analysis for the Catoctin Creek watershed.

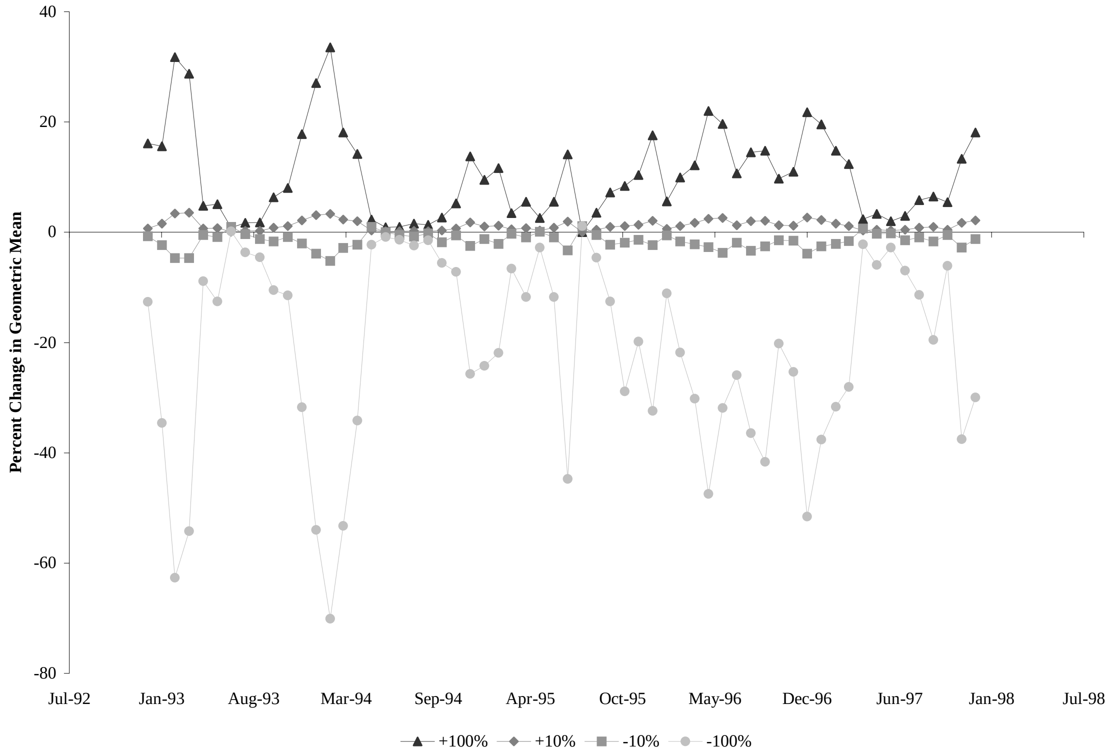

Figure 5.6 Results of sensitivity analysis on 30-day geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in land-based loadings.

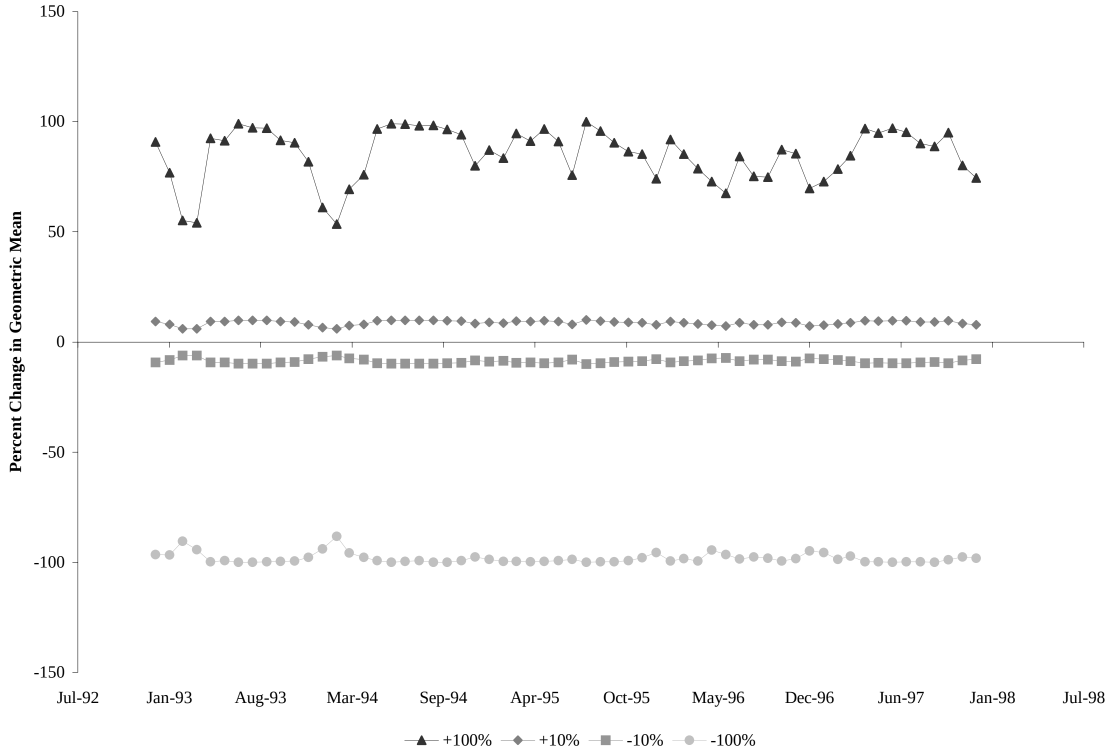

Figure 5.7 Results of sensitivity analysis on 30-day geometric-mean concentrations in the Catoctin Creek watershed, as affected by changes in loadings from direct nonpoint sources.

5.2 Incorporation of a Margin of Safety

A margin of safety (MOS) was incorporated into the TMDL in an effort to account for scientific errors inherent to the TMDL development process, measurement uncertainty in model parameters, and to account for trends which might prevent the water quality goal, as targeted by the TMDL, from being achieved. Scientific errors arise from our inability to fully describe mathematically the processes and mechanisms through which pollutants are delivered to the stream. Model calibration is an attempt to address these errors through adjusting model parameters until a suitable fit to observed data is achieved. Measurement uncertainty also introduces errors in the model calibration, because model parameters that are adjusted to non-representative conditions result in model simulations being biased either low or high. For example, observed data used for model calibration were collected for the purpose of detecting violations of the state's water quality standards. As a result, sample analyses are arbitrarily censored at a level above the state standard. This introduces modeling uncertainty during events that produce high pollutant concentrations. To ensure a pollutant reduction, long-term trends in pollutant sources must be considered in load allocations. For instance, if livestock populations within the targeted watershed are increasing, then a larger MOS might be appropriate to account for the expected increase in loads.

The MOS is a subjective value, representing a balance between complete certainty of reaching the in-stream standard and not meeting the standard. The MOS was entered explicitly as 5% of the maximum 30-day geometric mean standard (200 cfu/100 ml). The result was that allocation scenarios were developed with the goal of maintaining the modeled 30-day geometric mean below 190 cfu/100 ml.

5.3 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions were adjusted until the water quality standard was attained The TMDL developed for the Catoctin Creek watershed was based on the Virginia State Standard for fecal coliform. As detailed in Section 1.2, the fecal coliform standard states that the 30-day geometric-mean concentration shall not exceed 200 cfu/100 ml. As such, pollutant concentrations were modeled over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard, reduced by a margin of safety equal to 5%, was met (Figures 5.8 through 5.11). The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

5.3.1 Wasteload Allocations

There are four point sources currently permitted to discharge in the Catoctin Creek watershed (Figure 3.1 and Table 3.1). Two of these sources (i.e. Town of Purcellville WTP, and Town of Hamilton STP) discharge in the Upper South Fork Catoctin Creek drainage. The discharge from the Purcellville Water Treatment Plant is not permitted for fecal coliform control. For allocation runs, the plant was modeled as discharging the average recorded value of water, with no fecal coliform. The allocation for this point source is zero cfu/100 ml. The allocation for the Hamilton Sewage Treatment Plant is equivalent to its current permit levels (0.16 MGD and 200 cfu/100 ml).

There was one permitted discharge in the North Fork Catoctin Creek drainage, which comes from a private residential sewage treatment system. According to VADEQ, the general permit for the residential sewage treatment plant has expired, and correspondence with the permit holder indicated that while the permit was obtained, the system was never installed. As a result, no allocation was specified for this private residence. The remaining permitted discharge, the Waterford Sewage Treatment Plant, drains to the Lower South Fork Catoctin Creek. The allocation for this point is also equivalent to its current permit levels (0.058 MGD and 200 cfu/100 ml).

5.3.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (e.g. livestock, septic systems within 50 feet of a stream, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Within this framework, however, initial criteria that influenced developing load allocations included how sources were linked for representing existing conditions, and results from bacterial source tracking in the area. Direct deposition nonpoint sources were modeled with consistent loadings to the stream regardless of flow regime and had a significant impact on low flow concentrations. Bacterial source tracking during 2001-2002 sampling periods confirmed the presence of human, livestock and wildlife contamination.

With the impact of in-stream deposition very large, and the presence of human, livestock, and wildlife fecal material, an initial scenario was 100% reduction of uncontrolled residential discharges and 90% reduction in livestock stream access. All land-based allocations remained at existing conditions, that is, zero reduction.

This resulted in significant exceedances of the geometric mean standard (Tables 5.5 through 5.8, Scenario 1). The exceedances all occurred in historically low flow periods (Table 2.4). These periods are nearly totally dominated by in-stream deposition limiting the scenarios to achieve the target to a reduction of livestock to 100% (i.e. total exclusion from streams), reduction of wildlife, and/or reduction of lateral flow from septic systems within 50 feet of streams. However, 100% reduction of livestock direct deposition did not meet the standard (Tables 5.5 through 5.8, Scenario 2). Additional scenarios were explored incorporating a reduction in land-based loads (e.g. Tables 5.5 through 5.8, Scenario 3) resulting in minimal reduction in the percent of exceedances

As required by contract, the TMDL allocations were to be developed using the State's thirty-day geometric mean standard for fecal coliform. The geometric mean is designed to diminish the effect of a small number of extremely large observations, if the majority of observations are within acceptable limits. Because of this, it becomes important to understand the proportions of runoff events and low flow conditions within a thirty-day window. Analyses, conducted during previous studies, examined long-term rainfall data collected in Virginia and indicated that, on average, less than ten percent of the time within any thirty-day window was there a potential runoff event. Conversely, 90 percent of the time water quality was not directly impacted by surface runoff. So, the impact of the runoff events was relatively small, and the effect of reducing land-based loads was similarly small, as observed in the TMDL analysis (Tables 5.5 through 5.8, Scenario 3). As an example: Assuming that runoff events impact in-stream concentrations 10% of the time, if the geometric mean of fecal coliform concentrations during non-runoff event periods is 100 cfu/100 ml, then the geometric mean of fecal coliform concentrations during runoff events could be as much as 3 orders of magnitude greater and the state's water quality standard (30-day, geometric mean < 200 cfu/100 ml) would still be met.

While Figure 5.6 shows that a significant reduction in the 30-day geometric mean concentration can be achieved through a reduction in the land-based sources during wet seasons, it is important to remember that the geometric mean is not an additive quantity. Therefore, a reduction in the land-based sources is not necessary in order to meet the standard. Since violations during the dry seasons were not influenced by the land-based sources, reductions in the direct deposition sources were necessary to reach the standard.

Additional scenarios were modeled to achieve the target through the reduction of direct deposition, the dominant impacting source for these low flow conditions. A scenario including lateral flow from septic systems within 50 feet of streams had no measurable impact on the geometric mean for the low flow period (Table 5.5 through 5.8, Scenario 4). A scenario removing all sources except wildlife direct deposition resulted in continued exceedances in fall 1993, summer 1994 and summer 1997, periods of particularly low flows (Table 5.5 through 5.8, Scenario 5).

Several model runs were made investigating scenarios that involved the reduction of wildlife required to meet the standard for the low flow condition (Table 5.5 and 5.6, Scenarios 6-8; Table 5.7, Scenario 6; and Table 5.8, Scenarios 6-7). The final scenario involved a 91%, 93%, 25%, and 85% reductions, in the Upper South Fork Catoctin Creek (Table 5.5, Scenario 8; Figure 5.8), North Fork Catoctin Creek (Table 5.6, Scenario 8; Figure 5.9), Lower South Fork Catoctin Creek (Table 5.7, Scenario 6; Figure 5.10), and Catoctin Creek (Table 5.8, Scenario 7; Figure 5.11), respectively. In meeting the standard during the dry seasons, reductions were sufficient so as not to require a reduction in land-based sources during the wet seasons.

The load allocation for the Upper South Fork Catoctin Creek becomes no reduction of land applied fecal material, no reduction of septic systems within 50 feet of streams since the impact was negligible, 100% reduction of livestock in-stream deposition, 100% reduction of uncontrolled residential discharges, and 91% reduction of wildlife in-stream deposition (Tables 5.9 and 5.10). The load allocation for the North Fork Catoctin Creek becomes no reduction of land applied fecal material, no reduction of septic systems within 50 feet of streams since the impact was negligible, 100% reduction of livestock in-stream deposition, 100% reduction of uncontrolled residential discharges and 93% reduction of wildlife in-stream deposition (Tables 5.11 and 5.12). The load allocation for the Lower South Fork Catoctin Creek becomes no reduction of land applied fecal material, no reduction of septic systems within 50 feet of streams since the impact was negligible, 100% reduction of livestock in-stream deposition, 100% reduction of uncontrolled residential discharges and 25% reduction of wildlife in-stream deposition (Tables 5.13 and 5.14). The load allocation for the main stem of Catoctin Creek becomes no reduction of land applied fecal material, no reduction of septic systems within 50 feet of streams since the impact was negligible, 100% reduction of livestock in-stream deposition, 100% reduction of uncontrolled residential discharges and 85% reduction of wildlife in-stream deposition (Tables 5.15 and 5.16). Although there is no reduction of land applied fecal material, implicit in allocation is a need to maintain loadings at or below the current levels.

Table 5.5 Percentage of 30-day geometric mean values exceeding 190 cfu/100 ml fecal coliform in the Upper South Fork Catoctin Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition					Percentage of Days with 30-day GM>190 cfu/100ml
	Direct Wildlife Deposits	Direct Cattle Deposits	NPS from Land Segments	NPS From Straight Pipes	Direct Septic Lateral Flow	
1	0	90	0	100	0	10.46
2	0	100	0	100	0	5.98
3	0	100	50	100	0	5.62
4	0	100	0	100	100	5.98
5	0	100	100	100	100	5.05
6	75	100	0	100	0	1.58
7	90	100	0	100	0	0.26
8	91	100	0	100	0	0.00

Table 5.6 Percentage of 30-day geometric mean values exceeding 190 cfu/100 ml fecal coliform in the North Fork Catoctin Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition					Percentage of Days with 30-day GM>190 cfu/100ml
	Direct Wildlife Deposits	Direct Cattle Deposits	NPS from Land Segments	NPS From Straight Pipes	Direct Septic Lateral Flow	
1	0	90	0	100	0	13.26
2	0	100	0	100	0	8.03
3	0	100	50	100	0	6.64
4	0	100	0	100	100	8.03
5	0	100	100	100	100	5.85
6	75	100	0	100	0	2.61
7	90	100	0	100	0	0.77
8	93	100	0	100	0	0.00

Table 5.7 Percentage of 30-day geometric mean values exceeding 190 cfu/100 ml fecal coliform in the Lower South Fork Catoctin Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition					Percentage of Days with 30-day GM>190 cfu/100ml
	Direct Wildlife Deposits	Direct Cattle Deposits	NPS from Land Segments	NPS From Straight Pipes	Direct Septic Lateral Flow	
1	0	90	0	100	0	7.21
2	0	100	0	100	0	4.68
3	0	100	50	100	0	4.34
4	0	100	0	100	100	4.68
5	0	100	100	100	100	3.12
6	25	100	0	100	0	0.00

Table 5.8 Percentage of 30-day geometric mean values exceeding 190 cfu/100 ml fecal coliform in the Catoctin Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition					Percentage of Days with 30-day GM>190 cfu/100ml
	Direct Wildlife Deposits	Direct Cattle Deposits	NPS from Land Segments	NPS From Straight Pipes	Direct Septic Lateral Flow	
1	0	90	0	100	0	6.85
2	0	100	0	100	0	5.13
3	0	100	50	100	0	4.88
4	0	100	0	100	100	5.13
5	0	100	100	100	100	4.40
6	75	100	0	100	0	1.08
7	85	100	0	100	0	0.00

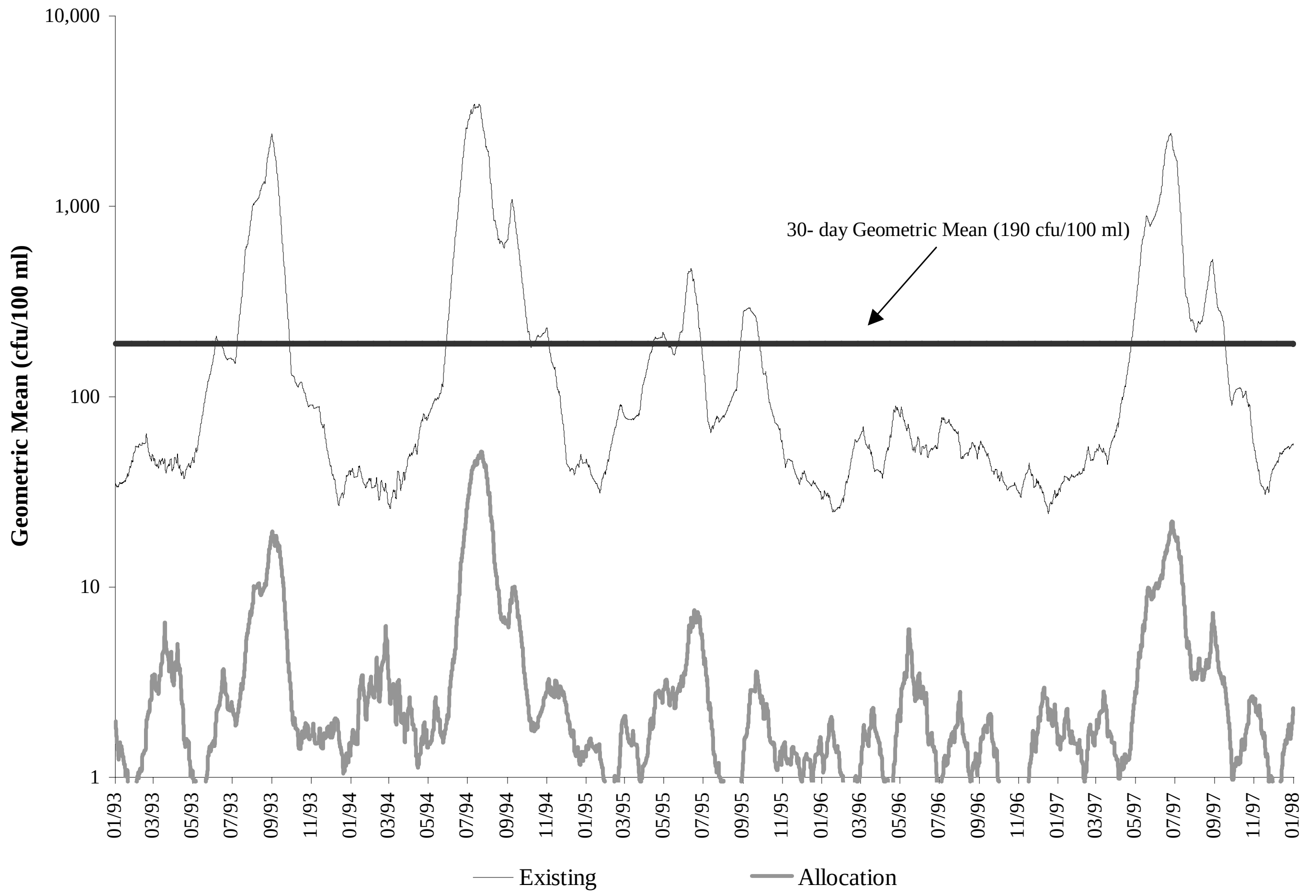

Figure 5.8 Allocation and existing scenarios for the Upper South Fork Catoctin Creek impairment.

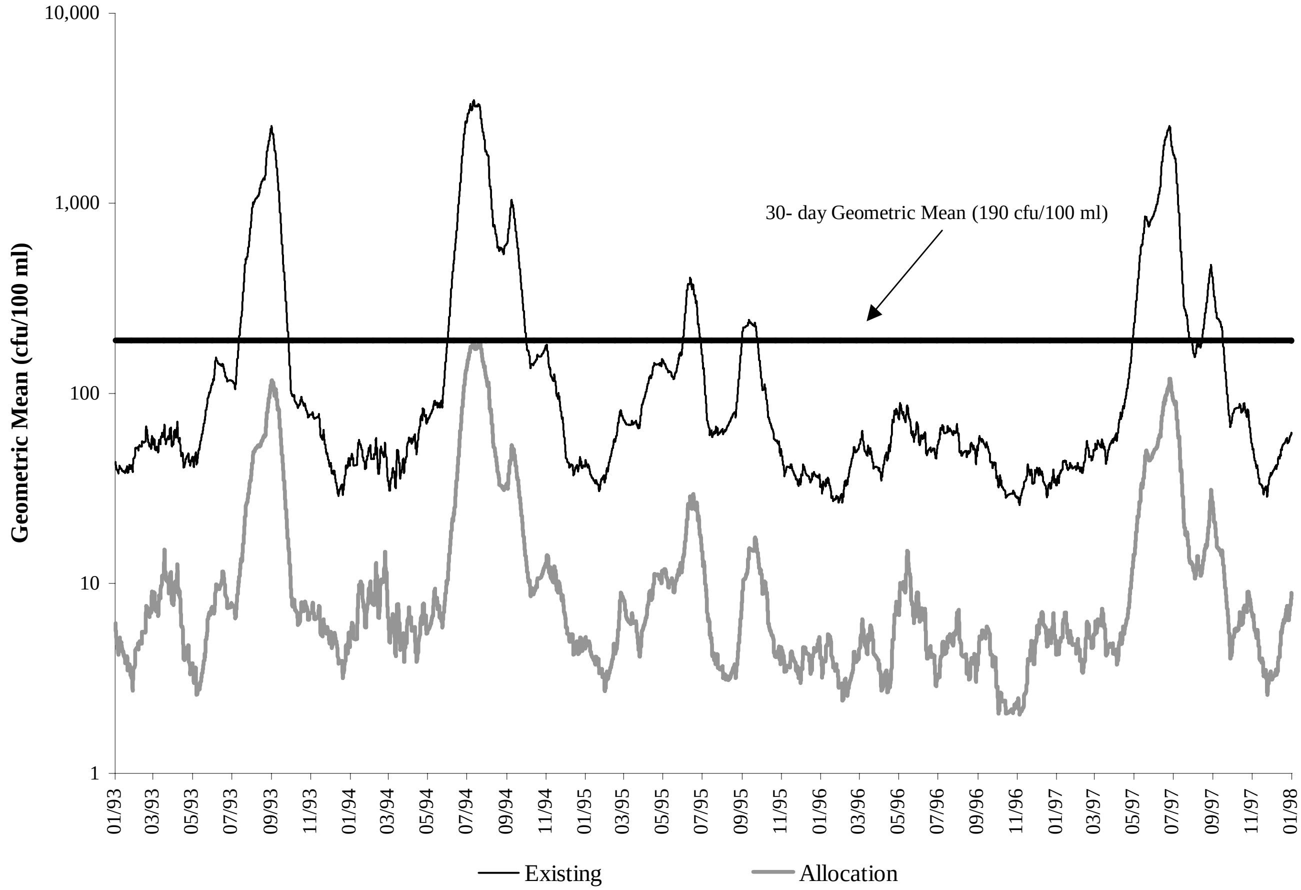

Figure 5.9 Allocation and existing scenarios for the Lower South Fork Catoctin Creek impairment.

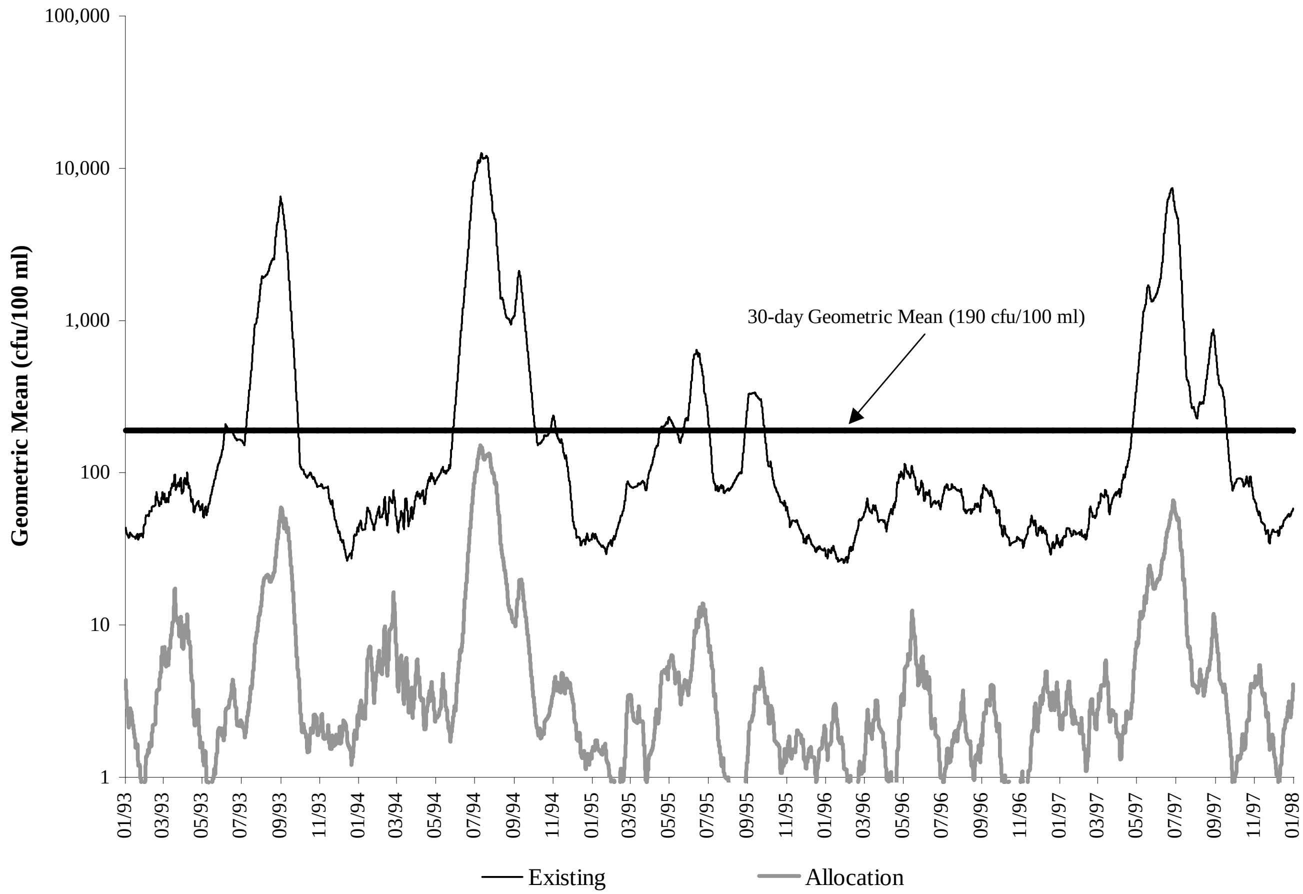

Figure 5.10 Allocation and existing scenarios for the North Fork Catoctin Creek impairment.

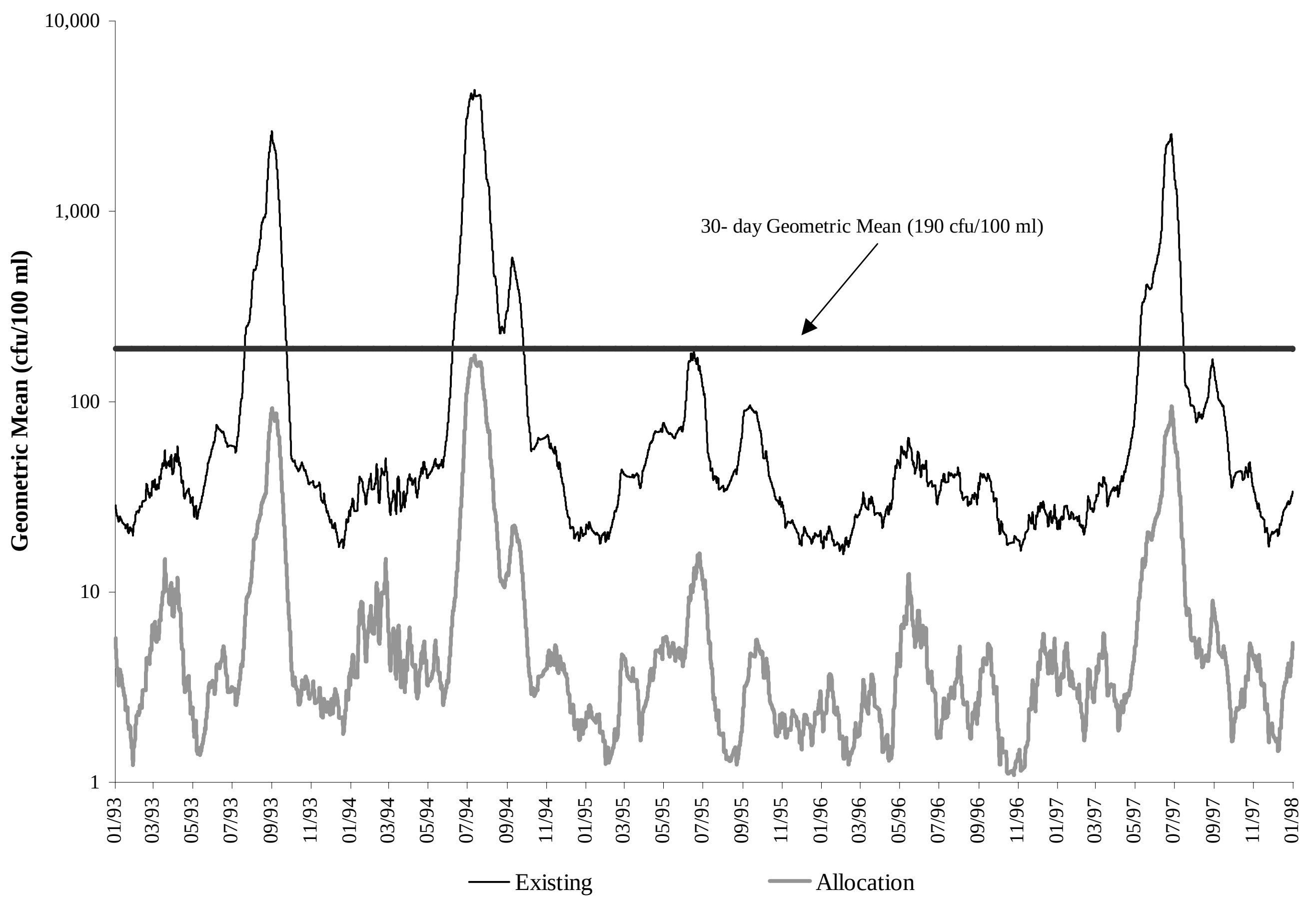

Figure 5.11 Allocation and existing scenarios for the Catoctin Creek impairment.

Table 5.9 Land-based nonpoint source load reductions in the Upper South Fork Catoctin Creek impairment for final allocation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	1.36E+14	1.36E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	5.54E+12	5.54E+12	0
Residential	2.28E+14	2.28E+14	0
Cropland	5.10E+14	5.10E+14	0
Livestock Operations	3.43E+13	3.43E+13	0
Farmstead	1.80E+13	1.80E+13	0
Unimproved Pasture	3.28E+13	3.28E+13	0
Improved Pasture	1.39E+15	1.39E+15	0
Potential Livestock Access	5.98E+13	6.95E+13	-16

Table 5.10 Land-based nonpoint source load reductions in the Lower South Fork Catoctin Creek impairment for final allocation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	7.35E+13	7.35E+13	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	1.32E+12	1.32E+12	0
Residential	6.48E+13	6.48E+13	0
Cropland	4.90E+12	4.90E+12	0
Livestock Operations	0.00E+00	0.00E+00	0
Farmstead	1.11E+13	1.11E+13	0
Unimproved Pasture	2.75E+13	2.75E+13	0
Improved Pasture	8.58E+14	8.58E+14	0
Potential Livestock Access	3.66E+13	4.08E+13	-11

Table 5.11 Land-based nonpoint source load reductions in the North Fork Catoctin Creek impairment for final allocation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	2.14E+14	2.14E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	3.41E+10	3.41E+10	0
Residential	6.89E+13	6.89E+13	0
Cropland	1.32E+15	1.32E+15	0
Livestock Operations	0.00E+00	0.00E+00	0
Farmstead	1.02E+13	1.02E+13	0
Unimproved Pasture	3.70E+13	3.70E+13	0
Improved Pasture	1.96E+15	1.96E+15	0
Potential Livestock Access	8.36E+13	1.00E+14	-20

Table 5.12 Land-based nonpoint source load reductions in the Catoctin Creek impairment for final allocation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	4.45E+14	4.45E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	2.53E+11	2.53E+11	0
Residential	1.85E+14	1.85E+14	0
Cropland	5.05E+13	5.05E+13	0
Livestock Operations	1.09E+10	1.09E+10	0
Farmstead	2.36E+13	2.36E+13	0
Unimproved Pasture	9.14E+13	9.14E+13	0
Improved Pasture	3.02E+15	3.02E+15	0
Potential Livestock Access	1.15E+14	1.32E+14	-14

Table 5.13 Load reductions to direct nonpoint sources in Upper South Fork Catoctin Creek impairment for final allocation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife (cfu/year) Allocated Load	Wildlife (cfu/year) % Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes (cfu/year) Allocated Load	Straight Pipes (cfu/year) % Red.
1	3.09E+10	2.78E+09	91	6.86E+09	0.00E+00	100
2	1.81E+11	1.63E+10	91	5.04E+10	0.00E+00	100
3	8.78E+11	7.90E+10	91	3.98E+10	0.00E+00	100
4	8.26E+11	7.44E+10	91	1.77E+11	0.00E+00	100
TOTAL	1.92E+12	1.72E+11	91	2.74E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow (cfu/year) Allocated Load	Lateral Flow (cfu/year) % Red.	Livestock (cfu/year) Existing Load	Livestock (cfu/year) Allocated Load	Livestock (cfu/year) % Red.
1	0.00E+00	0.00E+00	--	1.55E+12	0.00E+00	100
2	1.37E+08	1.37E+08	0	7.81E+11	0.00E+00	100
3	1.80E+08	1.80E+08	0	2.52E+12	0.00E+00	100
4	9.10E+08	9.10E+08	0	4.86E+12	0.00E+00	100
TOTAL	1.23E+09	1.23E+09	0	9.71E+12	0.00E+00	100

Table 5.14 Load reductions to direct nonpoint sources in Lower South Fork Catoctin Creek impairment for final allocation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife (cfu/year) Allocated Load	Wildlife (cfu/year) % Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes (cfu/year) Allocated Load	Straight Pipes (cfu/year) % Red.
5	9.80E+11	7.35E+11	25	9.10E+10	0.00E+00	100
6	4.02E+11	3.01E+11	25	4.18E+09	0.00E+00	100
TOTAL	1.38E+12	1.04E+12	25	9.52E+10	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow (cfu/year) Allocated Load	Lateral Flow (cfu/year) % Red.	Livestock (cfu/year) Existing Load	Livestock (cfu/year) Allocated Load	Livestock (cfu/year) % Red.
5	3.64E+08	3.64E+08	0	3.50E+12	0.00E+00	100
6	1.85E+07	1.85E+07	0	7.81E+11	0.00E+00	100
TOTAL	3.82E+08	3.82E+08	0	4.28E+12	0.00E+00	100

Table 5.15 Load reductions to direct nonpoint sources in North Fork Catoctin Creek impairment for final allocation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife Allocated Load	Wildlife % Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes Allocated Load	Straight Pipes % Red.
7	1.58E+11	1.11E+10	93	3.68E+10	0.00E+00	100
8	5.81E+11	4.07E+10	93	3.24E+10	0.00E+00	100
9	5.24E+11	3.67E+10	93	2.30E+10	0.00E+00	100
10	1.24E+12	8.67E+10	93	2.00E+10	0.00E+00	100
TOTAL	2.50E+12	1.75E+11	93	1.12E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow Allocated Load	Lateral Flow % Red.	Livestock (cfu/year) Existing Load	Livestock Allocated Load	Livestock % Red.
7	2.22E+08	2.22E+08	0	9.44E+12	0.00E+00	100
8	1.28E+08	1.28E+08	0	2.72E+12	0.00E+00	100
9	0.00E+00	0.00E+00	--	7.81E+11	0.00E+00	100
10	1.67E+08	1.67E+08	0	3.88E+12	0.00E+00	100
TOTAL	5.17E+08	5.17E+08	0	1.68E+13	0.00E+00	100

Table 5.16 Load reductions to direct nonpoint sources in Catoctin Creek impairment for final allocation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife Allocated Load	Wildlife % Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes Allocated Load	Straight Pipes % Red.
11	9.53E+11	1.43E+11	85	1.61E+10	0.00E+00	100
12	1.61E+12	2.41E+11	85	4.68E+10	0.00E+00	100
13	6.29E+11	9.44E+10	85	1.47E+10	0.00E+00	100
14	1.59E+12	2.38E+11	85	3.74E+10	0.00E+00	100
15	8.21E+11	1.23E+11	85	7.43E+10	0.00E+00	100
16	1.06E+12	1.59E+11	85	3.56E+10	0.00E+00	100
TOTAL	6.65E+12	9.98E+11	85	2.25E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow Allocated Load	Lateral Flow % Red.	Livestock (cfu/year) Existing Load	Livestock Allocated Load	Livestock % Red.
11	9.46E+07	9.46E+07	0	3.47E+12	0.00E+00	100
12	4.99E+08	4.99E+08	0	3.88E+12	0.00E+00	100
13	2.91E+07	2.91E+07	0	2.72E+12	0.00E+00	100
14	4.06E+08	4.06E+08	0	3.10E+12	0.00E+00	100
15	3.64E+08	3.64E+08	0	3.03E+12	0.00E+00	100
16	3.46E+08	3.46E+08	0	7.81E+11	0.00E+00	100
TOTAL	1.74E+09	1.74E+09	0	1.70E+13	0.00E+00	100

Table 5.17 Average annual loads (cfu/year) modeled after TMDL allocation in the Upper South Fork Catoctin Creek, Lower South Fork Catoctin Creek, North Fork Catoctin Creek, and Catoctin Creek watersheds.

Impairment	WLA[1]	LA	MOS	TMDL
Upper South Fork Catoctin Creek	4.42E+11	1.03E+14	2.64E+12	1.06E+14
Lower South Fork Catoctin Creek	1.60E+11	9.30E+14	3.92E+12	9.34E+14
North Fork Catoctin Creek	0.00E+00	3.27E+14	2.69E+12	3.30E+14
Catoctin Creek	0.00E+00	8.55E+14	1.08E+12	8.56E+14

1 The point sources permitted for fecal control in the Catoctin Creek drainage are Hamiltion STP (VPDES # VA0020974) and Waterford STP (VPDES # VA0060500). For Hamilton STP, a design flow of 0.16 MGD at a fecal coliform concentration of 200 cfu/100 ml results in a WLA of 4.42E+11 cfu/year. For Waterford STP, a design flow of 0.058 MGD at a fecal coliform concentration of 200 cfu/100 ml results in a WLA of 1.60E+11 cfu/year.

Future growth was estimated and projected to the year 2006. Population growth was based on a 96% increase for the period from 1990 through 2000 for Loudoun County (USCB, 2000). As a result, septic failure rates were projected to increase 48% for the period 2001-2006. Beef numbers were found to be decreasing at the rate of 7.65% per year for Loudoun County (VASS, 1995; VASS, 2000). While these numbers are on the decline horse numbers are increasing at the same rate, replacing beef cattle and occupying the same pasture. Swine and dairy numbers were found to be stable for the projected period. For the 2006 projection, the percent increase in land-based and directly deposited waste was calculated. Because the TMDL specifies 100% exclusion of livestock from streams and 25-93% reduction in wildlife direct loadings, direct load allocations for this projection were expected to be approximately 0%. Land-based waste was projected to increase by 1.8%, corresponding to an increase in the maximum 30-day geometric mean of, in a worst-case scenario, 0.6 cfu/100 ml. These projected increases should not be enough to cause violations of the standard during critical conditions. Additionally, there is a high degree of uncertainty in predicting growth in a specific region based on statistics from a larger geographical area (i.e. Loudoun County). It is therefore recommended that water quality monitoring during implementation of the TMDL be used to determine if growth trends are impacting water quality.

6. IMPLEMENTATION

6.1 Reasonable Assurance for Implementation

6.1.1 Follow-up Monitoring

The Department of Environmental Quality will continue to monitor Catoctin Creek in accordance with its ambient monitoring program. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

6.1.2 Regulatory Framework

The goal of this TMDL is to establish a three-step path that will lead to expeditious attainment of water quality standards. The first step in this process was to develop load reductions for sources of fecal coliform bacteria to Catoctin Creek using a watershed model, and is the purpose of this report. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL and attain water quality standards.

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, including implementation plans as a TMDL requirement has been discussed for future federal regulations. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.197.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

6.1.3 Funding Sources

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA Conservation Reserve Enhancement Program, the USDA Environmental Quality Incentives Program, the state revolving loan programs, and the VA Water Quality Improvement Fund.

6.2 Implementation Plan

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementations are, 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties which exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially; and 5) it allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard.

While specific stage I goals for BMP implementation will be established as part of the implementation plan development process, some general guidelines and suggestions are outlined below.

In general, the Commonwealth intends for the required reductions to be implemented in an iterative process that addresses the sources with the largest impact on water quality first. For example, the most promising management practice in agricultural areas of the watershed is livestock exclusion from streams. This has been shown to be very effective in lowering fecal coliform concentrations in streams, both from the cattle deposits themselves and from additional buffering in the riparian zone. Additionally, reducing the human bacteria loading from failing septic systems and straight pipes should be a focus during the first stage because of its health implications.

The stage I water quality goal was to reduce the number of violations of the instantaneous standard to less than 10%. The stage I allocation developed for the Upper South Fork Catoctin Creek, Lower South Fork Catoctin Creek, North Fork Catoctin Creek, and Catoctin Creek requires a 100% reduction of uncontrolled residential discharges and a 89% reduction in livestock direct deposition to the stream (Tables 6.1 - 6.8)

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Table 6.1 Land-based nonpoint source load reductions in the Upper South Fork Catoctin Creek impairment for Stage I implementation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	1.36E+14	1.36E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	5.54E+12	5.54E+12	0
Residential	2.28E+14	2.28E+14	0
Cropland	5.10E+14	5.10E+14	0
Livestock Operations	3.43E+13	3.43E+13	0
Farmstead	1.80E+13	1.80E+13	0
Unimproved Pasture	3.28E+13	3.28E+13	0
Improved Pasture	1.39E+15	1.39E+15	0
Potential Livestock Access	5.98E+13	6.54E+13	-9

Table 6.2 Land-based nonpoint source load reductions in the Lower South Fork Catoctin Creek impairment for Stage I implementation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	7.35E+13	7.35E+13	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	1.32E+12	1.32E+12	0
Residential	6.48E+13	6.48E+13	0
Cropland	4.90E+12	4.90E+12	0
Livestock Operations	0.00E+00	0.00E+00	0
Farmstead	1.11E+13	1.11E+13	0
Unimproved Pasture	2.75E+13	2.75E+13	0
Improved Pasture	8.58E+14	8.58E+14	0
Potential Livestock Access	3.66E+13	3.90E+13	-7

Table 6.3 Land-based nonpoint source load reductions in the North Fork Catoctin Creek impairment for Stage I implementation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	2.14E+14	2.14E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	3.41E+10	3.41E+10	0
Residential	6.89E+13	6.89E+13	0
Cropland	1.32E+15	1.32E+15	0
Livestock Operations	0.00E+00	0.00E+00	0
Farmstead	1.02E+13	1.02E+13	0
Unimproved Pasture	3.70E+13	3.70E+13	0
Improved Pasture	1.96E+15	1.96E+15	0
Potential Livestock Access	8.36E+13	9.32E+13	-11

Table 6.4 Land-based nonpoint source load reductions in the Catoctin Creek impairment for Stage I implementation.

Land use	Total Annual Loading For Existing Run (cfu/yr)	Total Annual Loading For Allocation Run (cfu/yr)	Percent Reduction
Woodland	4.45E+14	4.45E+14	0
Water	0.00E+00	0.00E+00	0
Commercial & Services	2.53E+11	2.53E+11	0
Residential	1.85E+14	1.85E+14	0
Cropland	5.05E+13	5.05E+13	0
Livestock Operations	1.09E+10	1.09E+10	0
Farmstead	2.36E+13	2.36E+13	0
Unimproved Pasture	9.14E+13	9.14E+13	0
Improved Pasture	3.02E+15	3.02E+15	0
Potential Livestock Access	1.15E+14	1.25E+14	-8

Table 6.5 Load reductions to direct nonpoint sources in Upper South Fork Catoctin Creek impairment for Stage I implementation.

Subw'shed	Wildlife (cfu/year)			Straight Pipes (cfu/year)		
	Existing Load	Allocated Load	% Red.	Existing Load	Allocated Load	% Red.
1	3.09E+10	3.09E+10	0	6.86E+09	0.00E+00	100
2	1.81E+11	1.81E+11	0	5.04E+10	0.00E+00	100
3	8.78E+11	8.78E+11	0	3.98E+10	0.00E+00	100
4	8.26E+11	8.26E+11	0	1.77E+11	0.00E+00	100
TOTAL	1.92E+12	1.92E+12	0	2.74E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year)			Livestock (cfu/year)		
	Existing Load	Allocated Load	% Red.	Existing Load	Allocated Load	% Red.
1	0.00E+00	0.00E+00	--	1.55E+12	3.10E+11	80
2	1.37E+08	1.37E+08	0	7.81E+11	1.56E+11	80
3	1.80E+08	1.80E+08	0	2.52E+12	5.04E+11	80
4	9.10E+08	9.10E+08	0	4.86E+12	9.72E+11	80
TOTAL	1.23E+09	1.23E+09	0	9.71E+12	1.94E+12	80

Table 6.6 Load reductions to direct nonpoint sources in Lower South Fork Catoctin Creek impairment for Stage I implementation.

Subw'shed	Wildlife (cfu/year)			Straight Pipes (cfu/year)		
	Existing Load	Allocated Load	% Red.	Existing Load	Allocated Load	% Red.
5	9.80E+11	9.80E+11	0	9.10E+10	0.00E+00	100
6	4.02E+11	4.02E+11	0	4.18E+09	0.00E+00	100
TOTAL	1.38E+12	1.38E+12	0	9.52E+10	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year)			Livestock (cfu/year)		
	Existing Load	Allocated Load	% Red.	Existing Load	Allocated Load	% Red.
5	3.64E+08	3.64E+08	0	3.50E+12	7.00E+11	80
6	1.85E+07	1.85E+07	0	7.81E+11	1.56E+11	80
TOTAL	3.82E+08	3.82E+08	0	4.28E+12	8.56E+11	80

Table 6.7 Load reductions to direct nonpoint sources in North Fork Catoctin Creek impairment for Stage I implementation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife (cfu/year) Allocated Load	% Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes (cfu/year) Allocated Load	% Red.
7	1.58E+11	1.58E+11	0	3.68E+10	0.00E+00	100
8	5.81E+11	5.81E+11	0	3.24E+10	0.00E+00	100
9	5.24E+11	5.24E+11	0	2.30E+10	0.00E+00	100
10	1.24E+12	1.24E+12	0	2.00E+10	0.00E+00	100
TOTAL	2.50E+12	2.50E+12	0	1.12E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow (cfu/year) Allocated Load	% Red.	Livestock (cfu/year) Existing Load	Livestock (cfu/year) Allocated Load	% Red.
7	2.22E+08	2.22E+08	0	9.44E+12	1.89E+12	80
8	1.28E+08	1.28E+08	0	2.72E+12	5.44E+11	80
9	0.00E+00	0.00E+00	--	7.81E+11	1.56E+11	80
10	1.67E+08	1.67E+08	0	3.88E+12	7.76E+11	80
TOTAL	5.17E+08	5.17E+08	0	1.68E+13	3.36E+12	80

Table 6.8 Load reductions to direct nonpoint sources in Catoctin Creek impairment for Stage I implementation.

Subw'shed	Wildlife (cfu/year) Existing Load	Wildlife (cfu/year) Allocated Load	% Red.	Straight Pipes (cfu/year) Existing Load	Straight Pipes (cfu/year) Allocated Load	% Red.
11	9.53E+11	9.53E+11	0	1.61E+10	0.00E+00	100
12	1.61E+12	1.61E+12	0	4.68E+10	0.00E+00	100
13	6.29E+11	6.29E+11	0	1.47E+10	0.00E+00	100
14	1.59E+12	1.59E+12	0	3.74E+10	0.00E+00	100
15	8.21E+11	8.21E+11	0	7.43E+10	0.00E+00	100
16	1.06E+12	1.06E+12	0	3.56E+10	0.00E+00	100
TOTAL	6.65E+12	6.65E+12	0	2.25E+11	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year) Existing Load	Lateral Flow (cfu/year) Allocated Load	% Red.	Livestock (cfu/year) Existing Load	Livestock (cfu/year) Allocated Load	% Red.
11	9.46E+07	9.46E+07	0	3.47E+12	6.94E+11	80
12	4.99E+08	4.99E+08	0	3.88E+12	7.76E+11	80
13	2.91E+07	2.91E+07	0	2.72E+12	5.44E+11	80
14	4.06E+08	4.06E+08	0	3.10E+12	6.20E+11	80
15	3.64E+08	3.64E+08	0	3.03E+12	6.06E+11	80
16	3.46E+08	3.46E+08	0	7.81E+11	1.56E+11	80
TOTAL	1.74E+09	1.74E+09	0	1.70E+13	3.40E+12	80

Public participation during the implementation plan development process will include the formation of stakeholders committee and open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders committee will have the expressed purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from the Department of Environmental Quality, Department of Conservation and Recreation, Department of Health, local agricultural community, local urban community, and local governments. This committee will have responsibility for identifying corrective actions that are founded in practicality, establish a time line to insure expeditious implementation and set measurable goals and milestones for attaining water quality standards.

The development of the implementation plan is expected to be an iterative process, with monitoring data refining its final design. Subsequent refinements will be made as the progress toward meeting milestones and the expressed TMDL goals is assessed. As practices are implemented, periodic analyses of water quality conditions will be conducted to evaluate the progress toward meeting end goals.

6.3 Public Participation

The development of the Catoctin Creek TMDLs would not have been possible without public participation. The first public meeting was held in Lovettsville on October 23, 2001 to discuss the process for TMDL development, 10 people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. A public meeting notice was published in the *Leesburg Today* on October 12, 2001. There was a 30 day-public comment period and no written comments were received.

The second public meeting was held in Hillsboro on January 23, 2002 to discuss the source assessment input, bacterial source tracking, and model calibration data, 30 people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. A public meeting notice was also published in the *Loudoun Times Mirror* on January 16, 2002. A public service announcement was also made on WAGE Radio in the days prior to the meeting, and flyers were posted at stores and businesses in the watershed. There was a 30 day-public comment period and one comment letter was received.

The third public meeting was held in Hillsboro on March 26, 2002 to discuss the draft TMDL, 14 people attended. Copies of the draft TMDL were available for public distribution. The meeting was public noticed in the *Virginia Register*. A public notice was published in the *Loudoun Times Mirror* on March 13, 2002 and flyers were posted at stores and businesses in the watershed. There was a 30-day public comment period and no written comments were received.

Table 6.9 Public participation during TMDL development for the Catoctin Creek watershed.

Date	Location	Attendance[1]	Format
10/23/01	Lovettsville Community Center	10	
01/23/02	Old Stone Schoolhouse located at 37098 Charlestown Pike (Rt. 9) Hillsboro, VA	30	Open to public at large
3/26/02	Old Stone Schoolhouse located at 37098 Charlestown Pike (Rt. 9) Hillsboro, VA	14	Open to public at large

[1] The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to under estimate the actual attendance.

Prompted by comments from the second public meeting, local wastewater and water treatment facilities (i.e. Hamilton STP, Waterford STP, and Purcellville WTP) within the Catoctin Creek watershed were contacted for available rainfall data. The only attainable data was daily rainfall data collected at the Purcellville Water Treatment Plant, and was limited to the period April 2000-present (Steward, 2002).

This data was comparable to the precipitation data used in the modeling procedure. Discrepancies occurred during the summer months, which can be attributed to localized summer storm events. As a result, the 15-minute precipitation data collected at Lincoln and Mount Weather in Loudoun County, Virginia was used due to more comprehensive rainfall data.

APPENDIX A

FECAL COLIFORM DISTRIBUTIONS FOR EACH SAMPLING STATION IN CATOCTIN CREEK IMPAIRMENT

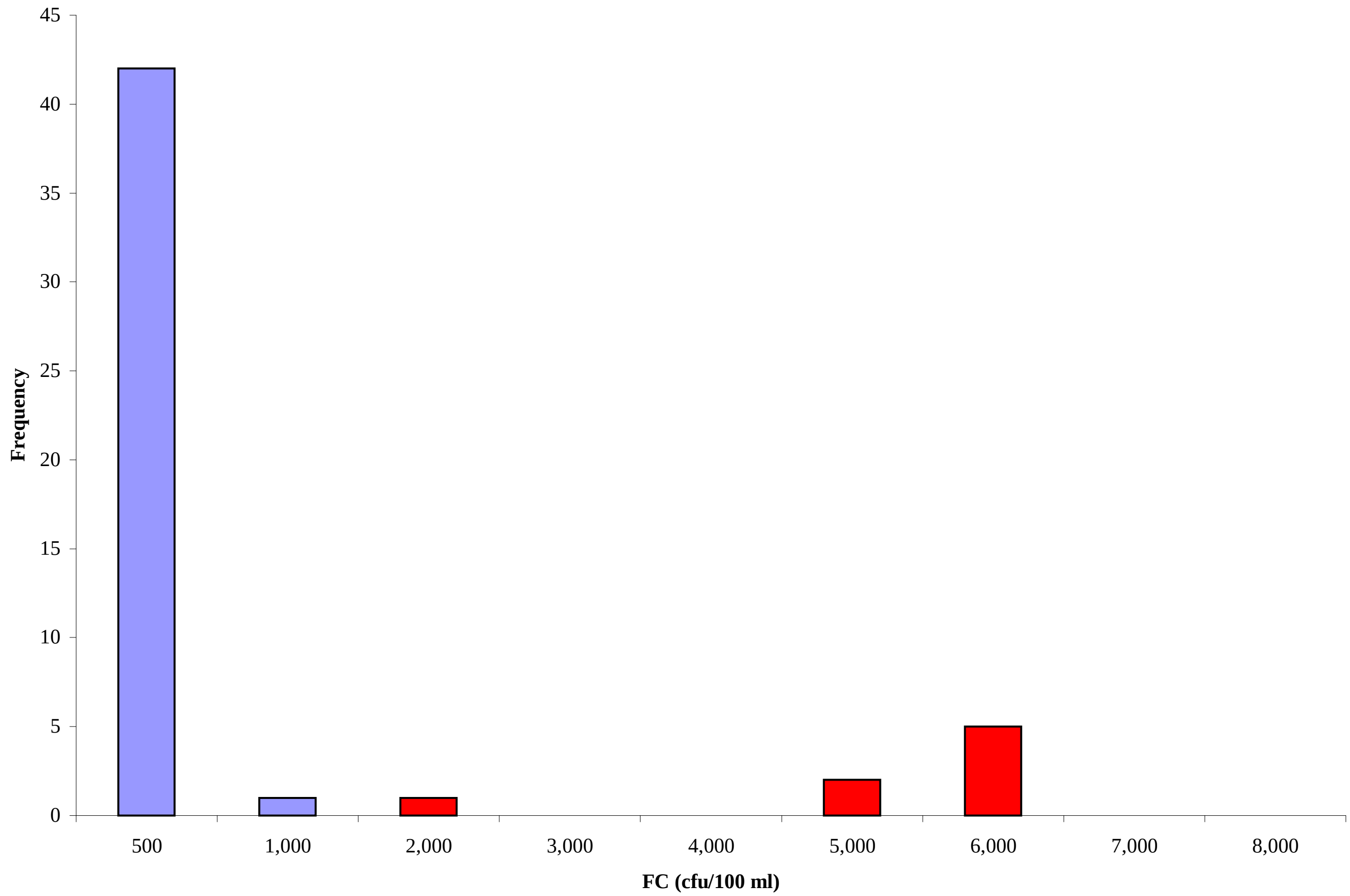

Figure A.1 Frequency analysis of fecal coliform concentrations at 1ACAX000.19 in the Catoctin Creek impairment.

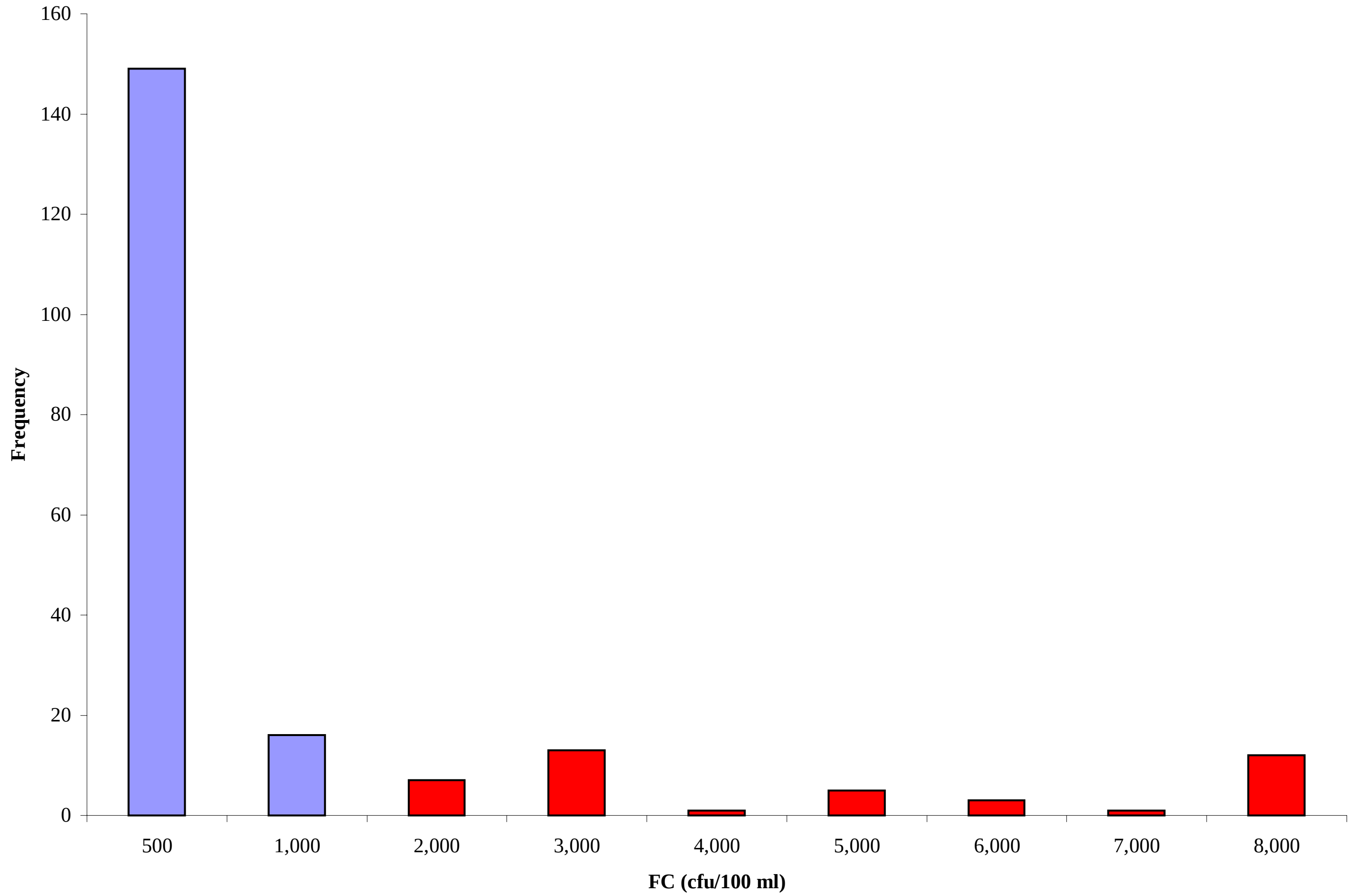

Figure A.2 Frequency analysis of fecal coliform concentrations at 1ACAX004.57 in the Catoctin Creek impairment.

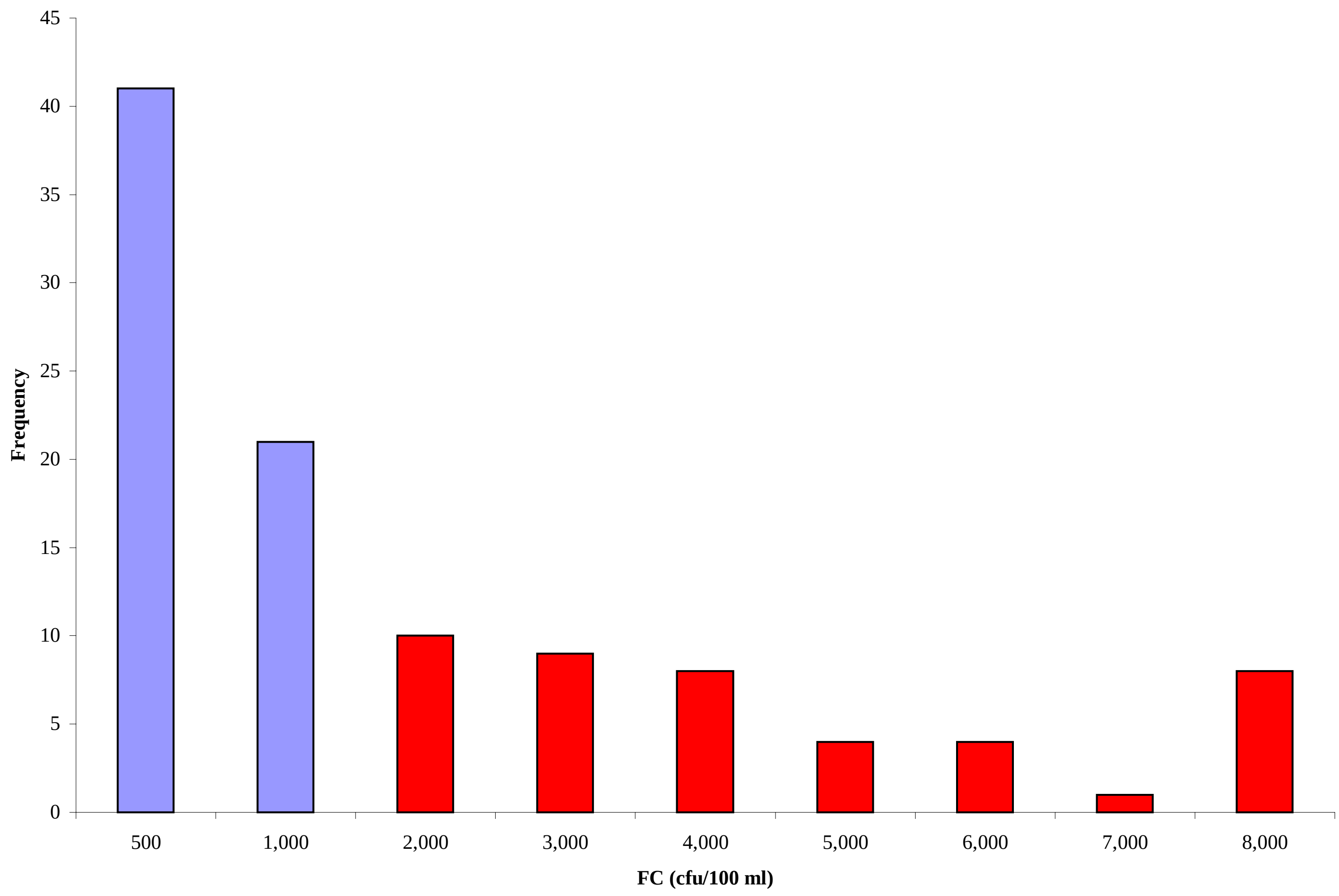

Figure A.3 Frequency analysis of fecal coliform concentrations at station 1ANOC000.42 in the North Fork Catoctin Creek impairment.

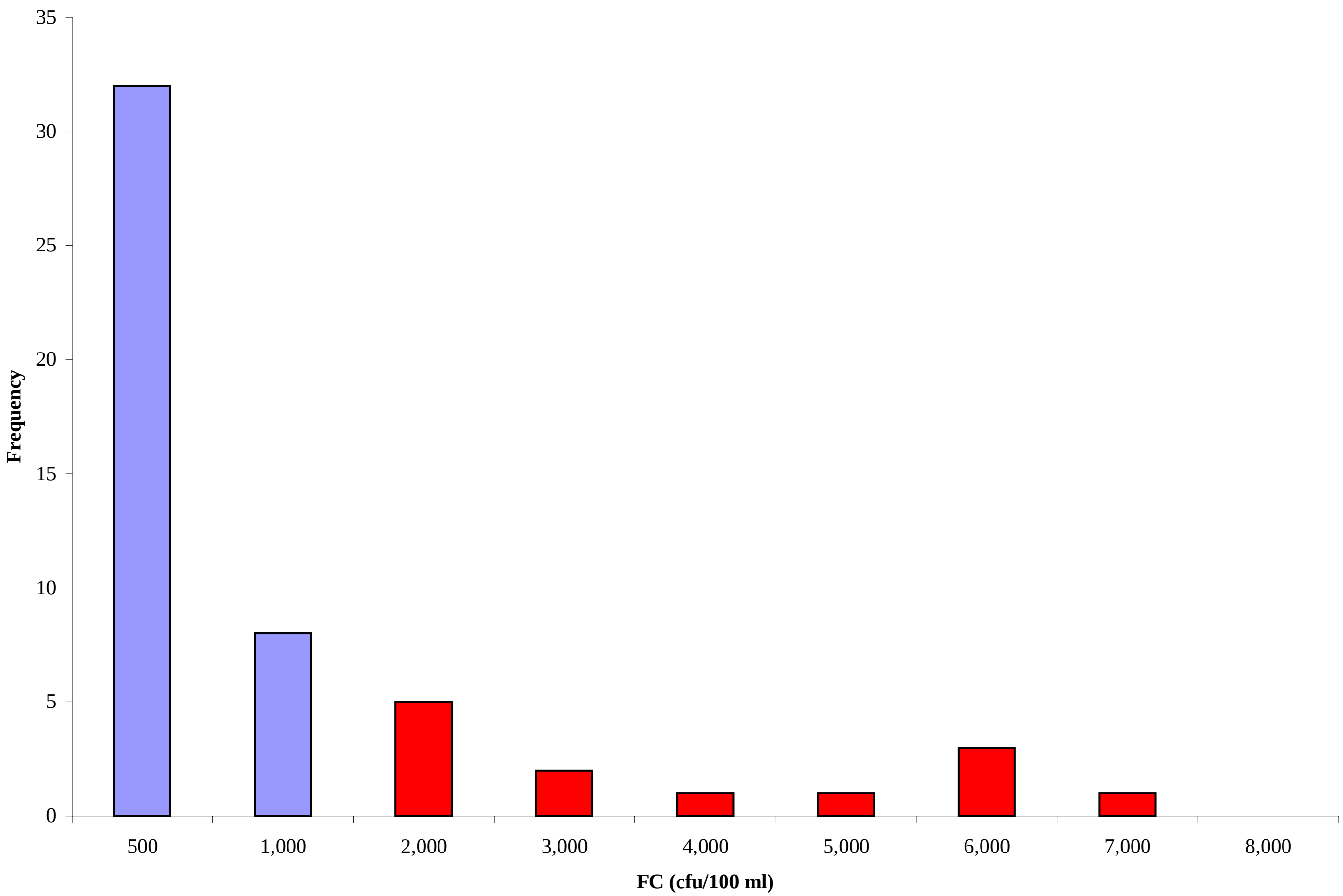

Figure A.4 Frequency analysis of fecal coliform concentrations at station 1ANOC004.38 in the North Fork Catoctin Creek impairment.

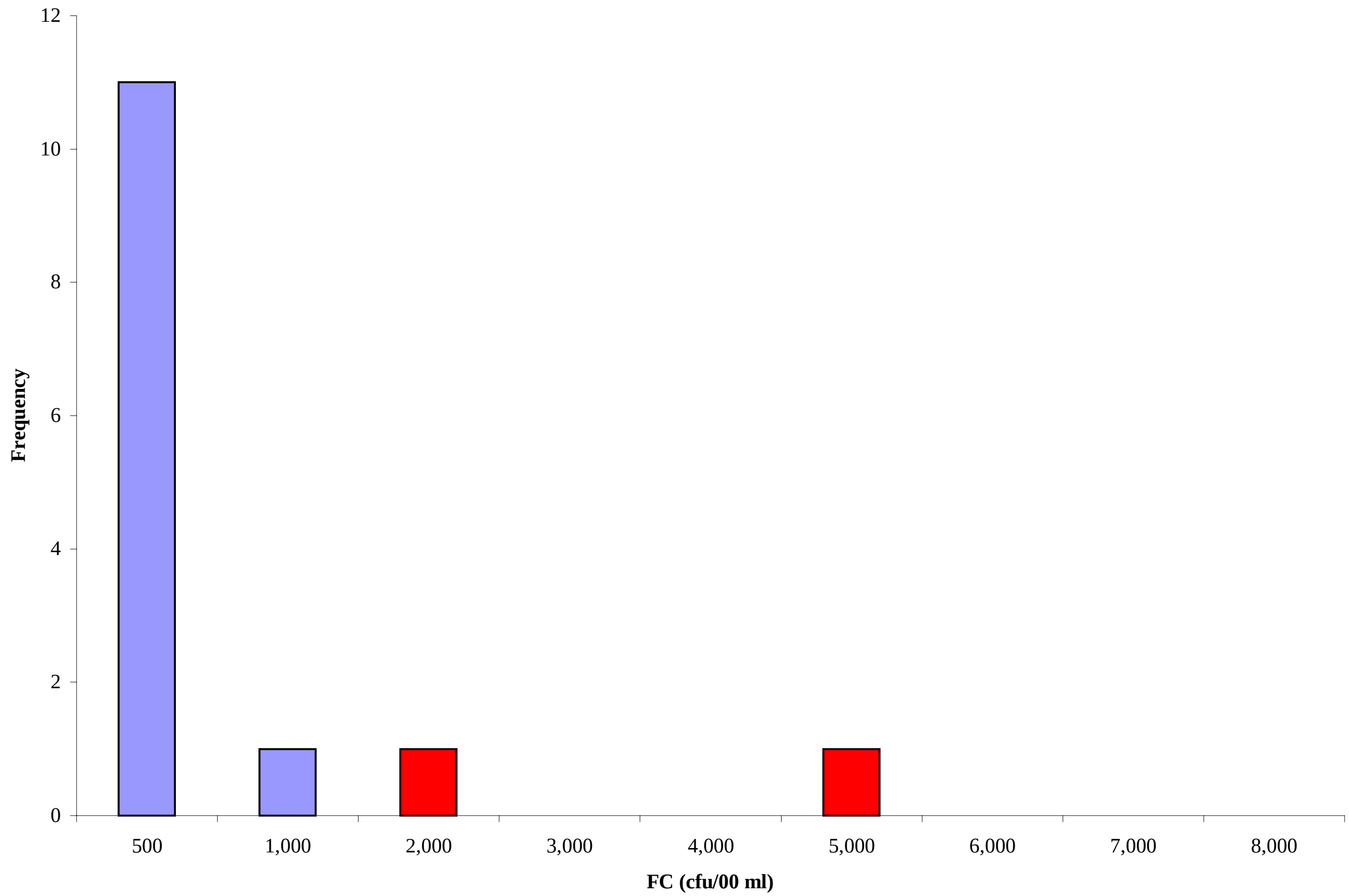

Figure A.5 Frequency analysis of fecal coliform concentrations at station 1ANOC009.13 in the North Fork Catoctin Creek impairment.

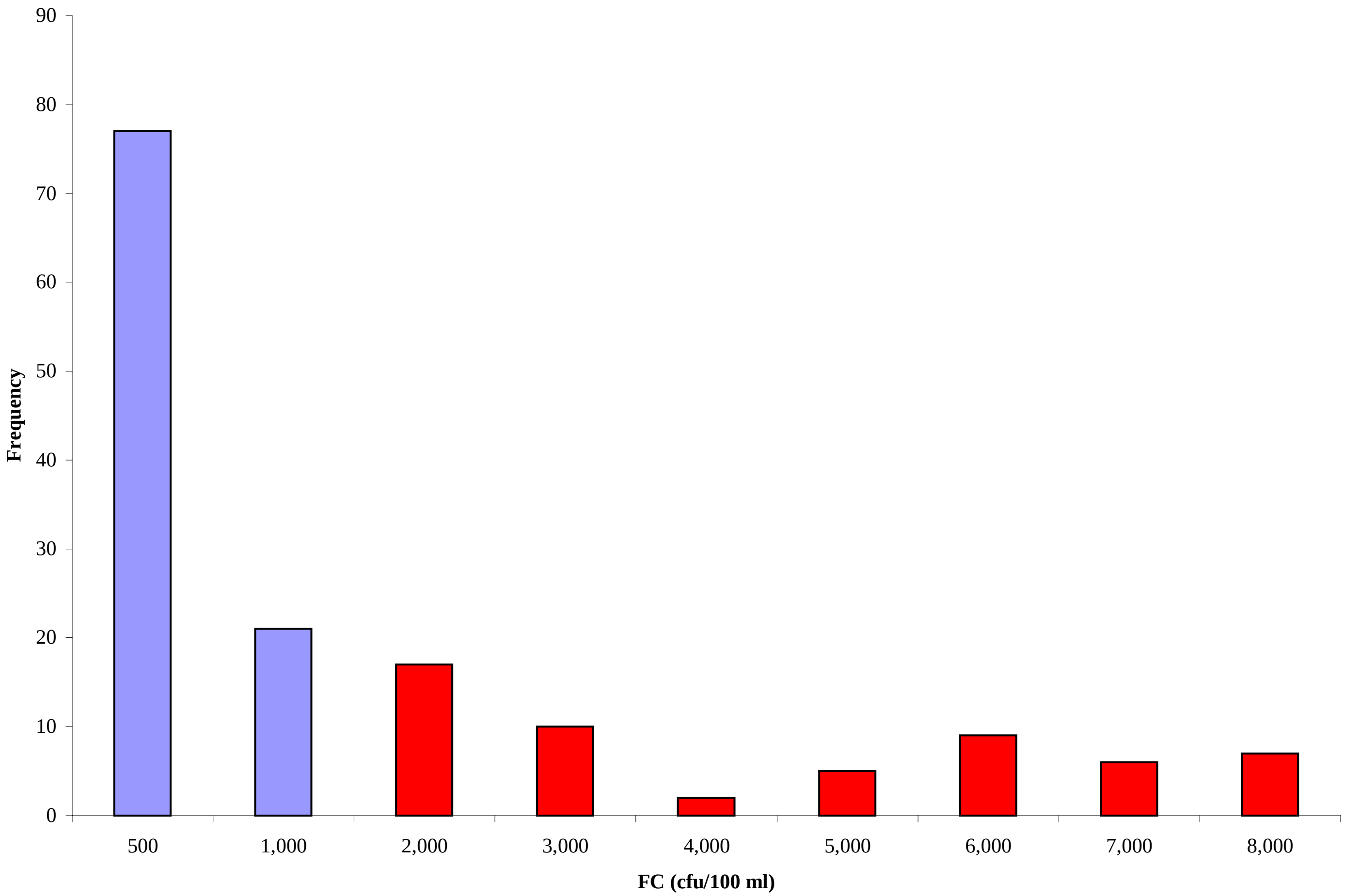

Figure A.6 Frequency analysis of fecal coliform concentrations at station 1ASOC001.66 in the Lower South Fork Catoctin Creek impairment.

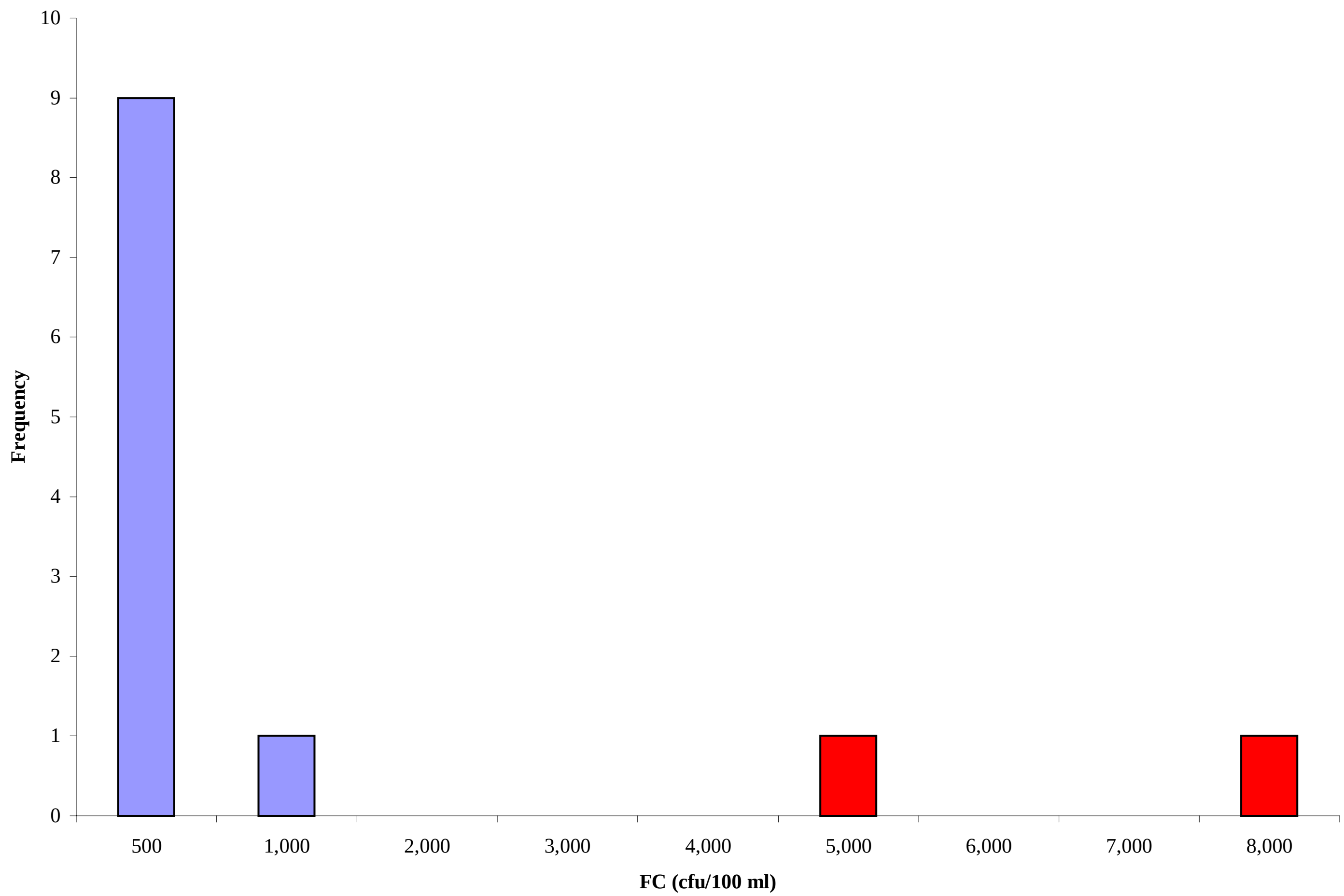

Figure A.7 Frequency analysis of fecal coliform concentrations at station 1ASOC007.06 in the Upper South Fork Catoctin Creek impairment.

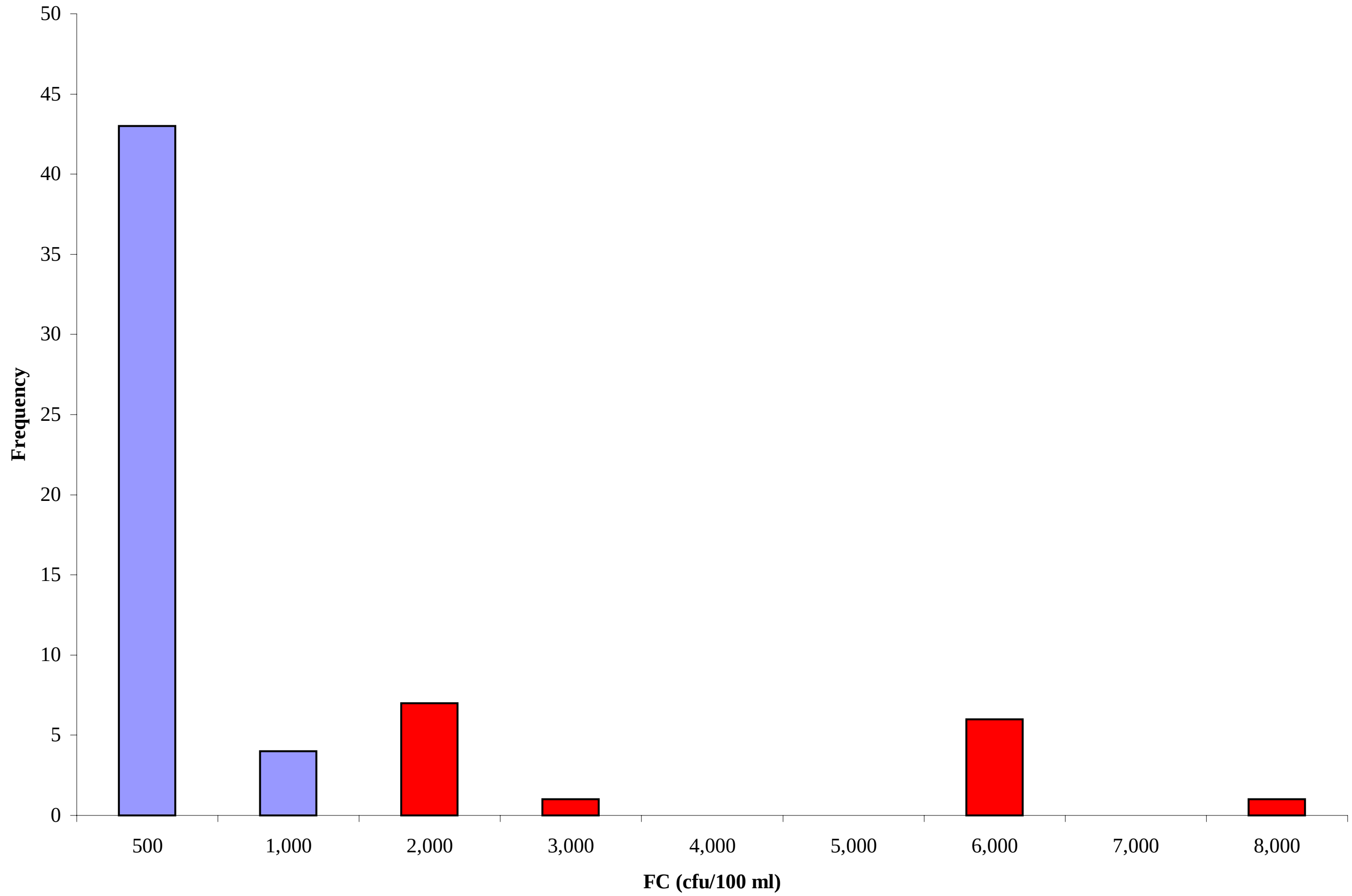

Figure A.8 Frequency analysis of fecal coliform concentrations at station 1ASOC011.82 in the Upper South Fork Catoctin Creek impairment.

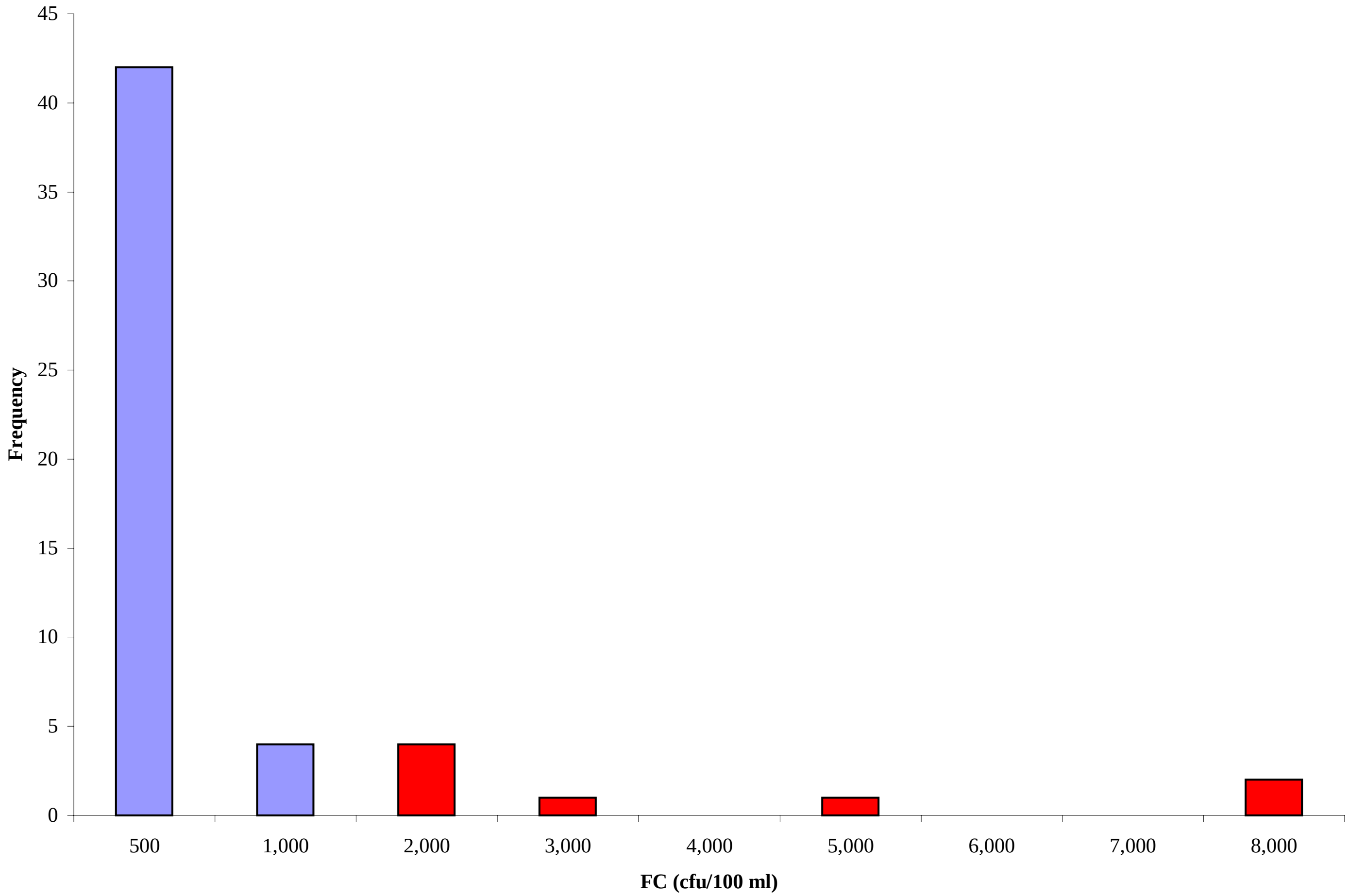

Figure A.9 Frequency analysis of fecal coliform concentrations at station 1AS0C012.38 in the Upper South Fork Catoctin Creek impairment.

APPENDIX B

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table B.1 Current conditions (2001) of land applied fecal coliform load for Upper South Fork Catoctin Creek.

	Woodland (cfu/ac*day)	Water (cfu/ac*day)	Commercial Services (cfu/ac*day)	Residential (cfu/ac*day)	Cropland (cfu/ac*day)
January	1.11E+08	0.00E+00	7.60E+07	1.32E+09	1.83E+08
February	1.11E+08	0.00E+00	7.60E+07	1.32E+09	2.01E+08
March	1.11E+08	0.00E+00	7.60E+07	1.32E+09	1.30E+09
April	1.09E+08	0.00E+00	7.60E+07	1.32E+09	1.30E+09
May	1.09E+08	0.00E+00	7.60E+07	1.32E+09	1.30E+09
June	1.09E+08	0.00E+00	7.60E+07	1.32E+09	7.64E+07
July	1.08E+08	0.00E+00	7.60E+07	1.32E+09	7.79E+07
August	1.08E+08	0.00E+00	7.60E+07	1.32E+09	7.79E+07
September	1.08E+08	0.00E+00	7.60E+07	1.32E+09	4.37E+08
October	1.08E+08	0.00E+00	7.60E+07	1.32E+09	1.30E+09
November	1.08E+08	0.00E+00	7.60E+07	1.32E+09	1.30E+09
December	1.11E+08	0.00E+00	7.60E+07	1.32E+09	1.83E+08

Table B.1 Current conditions (2001) of land applied fecal coliform load for Upper South Fork Catoctin Creek (Continued).

	Livestock Operations (cfu/ac*day)	Farmstead (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Potential Livestock Access (cfu/ac*day)
January	8.28E+09	6.62E+08	5.42E+08	4.71E+08	5.55E+08
February	8.28E+09	6.62E+08	5.42E+08	4.71E+08	6.02E+08
March	8.28E+09	6.61E+08	5.96E+08	5.29E+08	7.23E+08
April	8.28E+09	6.61E+08	5.93E+08	5.26E+08	8.44E+08
May	8.28E+09	6.61E+08	5.92E+08	5.25E+08	8.44E+08
June	8.28E+09	6.61E+08	5.89E+08	5.58E+08	9.65E+08
July	8.28E+09	6.60E+08	5.88E+08	5.58E+08	9.65E+08
August	8.28E+09	6.60E+08	5.88E+08	5.58E+08	9.65E+08
September	8.28E+09	6.60E+08	5.88E+08	5.20E+08	8.44E+08
October	8.28E+09	6.60E+08	5.85E+08	5.17E+08	7.23E+08
November	8.28E+09	6.60E+08	5.84E+08	5.16E+08	6.53E+08
December	8.28E+09	6.61E+08	5.84E+08	5.16E+08	5.55E+08

Table B.2 Current conditions (2001) of land applied fecal coliform load for Lower South Fork Catoctin Creek.

	Woodland (cfu/ac*day)	Water (cfu/ac*day)	Commercial Services (cfu/ac*day)	Residential (cfu/ac*day)	Cropland (cfu/ac*day)
January	1.25E+08	0.00E+00	9.76E+07	1.38E+09	5.30E+07
February	1.25E+08	0.00E+00	9.76E+07	1.38E+09	5.30E+07
March	1.25E+08	0.00E+00	9.76E+07	1.37E+09	5.30E+07
April	1.23E+08	0.00E+00	9.76E+07	1.37E+09	5.45E+07
May	1.23E+08	0.00E+00	9.76E+07	1.37E+09	5.45E+07
June	1.23E+08	0.00E+00	9.76E+07	1.37E+09	5.45E+07
July	1.22E+08	0.00E+00	9.76E+07	1.37E+09	5.60E+07
August	1.22E+08	0.00E+00	9.76E+07	1.37E+09	5.60E+07
September	1.22E+08	0.00E+00	9.76E+07	1.37E+09	5.60E+07
October	1.22E+08	0.00E+00	9.76E+07	1.37E+09	5.60E+07
November	1.22E+08	0.00E+00	9.76E+07	1.37E+09	5.60E+07
December	1.25E+08	0.00E+00	9.76E+07	1.37E+09	5.30E+07

Table B.2 Current conditions (2001) of land applied fecal coliform load for Lower South Fork Catoctin Creek (Continued).

	Livestock Operations (cfu/ac*day)	Farmstead (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Potential Livestock Access (cfu/ac*day)
January	0.00E+00	9.56E+08	5.75E+08	4.85E+08	6.06E+08
February	0.00E+00	9.55E+08	5.75E+08	4.85E+08	6.39E+08
March	0.00E+00	9.54E+08	6.13E+08	5.26E+08	7.25E+08
April	0.00E+00	9.54E+08	6.11E+08	5.24E+08	8.10E+08
May	0.00E+00	9.53E+08	6.10E+08	5.23E+08	8.10E+08
June	0.00E+00	9.52E+08	6.08E+08	5.21E+08	8.96E+08
July	0.00E+00	9.51E+08	6.07E+08	5.20E+08	8.96E+08
August	0.00E+00	9.51E+08	6.07E+08	5.20E+08	8.96E+08
September	0.00E+00	9.51E+08	6.07E+08	5.20E+08	8.10E+08
October	0.00E+00	9.51E+08	6.05E+08	5.17E+08	7.25E+08
November	0.00E+00	9.51E+08	6.04E+08	5.17E+08	6.76E+08
December	0.00E+00	9.54E+08	6.04E+08	5.17E+08	6.06E+08

Table B.3 Current conditions (2001) of land applied fecal coliform load for North Fork Catoctin Creek.

	Woodland (cfu/ac*day)	Water (cfu/ac*day)	Commercial Services (cfu/ac*day)	Residential (cfu/ac*day)	Cropland (cfu/ac*day)
January	9.78E+07	0.00E+00	3.78E+07	2.27E+09	7.55E+07
February	9.78E+07	0.00E+00	3.78E+07	2.27E+09	7.55E+07
March	9.78E+07	0.00E+00	3.78E+07	2.27E+09	9.14E+09
April	9.63E+07	0.00E+00	3.78E+07	2.27E+09	9.15E+09
May	9.63E+07	0.00E+00	3.78E+07	2.27E+09	9.15E+09
June	9.63E+07	0.00E+00	3.78E+07	2.26E+09	7.71E+07
July	9.47E+07	0.00E+00	3.78E+07	2.26E+09	7.86E+07
August	9.47E+07	0.00E+00	3.78E+07	2.26E+09	7.86E+07
September	9.47E+07	0.00E+00	3.78E+07	2.26E+09	7.86E+07
October	9.47E+07	0.00E+00	3.78E+07	2.26E+09	9.15E+09
November	9.47E+07	0.00E+00	3.78E+07	2.26E+09	9.15E+09
December	9.78E+07	0.00E+00	3.78E+07	2.27E+09	7.55E+07

Table B.3 Current conditions (2001) of land applied fecal coliform load for North Fork Catoctin Creek (Continued).

	Livestock Operations (cfu/ac*day)	Farmstead (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Potential Livestock Access (cfu/ac*day)
January	0.00E+00	7.61E+08	8.22E+08	6.73E+08	9.67E+08
February	0.00E+00	7.61E+08	8.22E+08	6.73E+08	1.04E+09
March	0.00E+00	7.60E+08	9.10E+08	7.40E+08	1.36E+09
April	0.00E+00	7.60E+08	9.07E+08	7.45E+08	1.68E+09
May	0.00E+00	7.60E+08	9.08E+08	7.50E+08	1.68E+09
June	0.00E+00	7.60E+08	9.03E+08	7.47E+08	2.01E+09
July	0.00E+00	7.59E+08	9.03E+08	7.50E+08	2.01E+09
August	0.00E+00	7.59E+08	9.03E+08	7.50E+08	2.01E+09
September	0.00E+00	7.59E+08	9.04E+08	7.54E+08	1.68E+09
October	0.00E+00	7.59E+08	8.99E+08	7.51E+08	1.36E+09
November	0.00E+00	7.59E+08	8.96E+08	7.45E+08	1.26E+09
December	0.00E+00	7.60E+08	8.93E+08	7.36E+08	9.67E+08

Table B.4 Current conditions (2001) of land applied fecal coliform load for Catoctin Creek.

	Woodland (cfu/ac*day)	Water (cfu/ac*day)	Commercial Services (cfu/ac*day)	Residential (cfu/ac*day)	Cropland (cfu/ac*day)
January	1.76E+08	0.00E+00	1.17E+08	2.05E+09	8.24E+07
February	1.76E+08	0.00E+00	1.17E+08	2.05E+09	8.24E+07
March	1.76E+08	0.00E+00	1.17E+08	2.05E+09	8.24E+07
April	1.75E+08	0.00E+00	1.17E+08	2.05E+09	8.39E+07
May	1.75E+08	0.00E+00	1.17E+08	2.05E+09	8.39E+07
June	1.75E+08	0.00E+00	1.17E+08	2.05E+09	8.39E+07
July	1.73E+08	0.00E+00	1.17E+08	2.05E+09	8.55E+07
August	1.73E+08	0.00E+00	1.17E+08	2.05E+09	8.55E+07
September	1.73E+08	0.00E+00	1.17E+08	2.05E+09	8.55E+07
October	1.73E+08	0.00E+00	1.17E+08	2.05E+09	8.55E+07
November	1.73E+08	0.00E+00	1.17E+08	2.05E+09	8.55E+07
December	1.76E+08	0.00E+00	1.17E+08	2.05E+09	8.24E+07

Table B.4 Current conditions (2001) of land applied fecal coliform load for Catoctin Creek (Continued).

	Livestock Operations (cfu/ac*day)	Farmstead (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Potential Livestock Access (cfu/ac*day)
January	3.79E+07	1.18E+09	5.84E+08	5.85E+08	6.38E+08
February	3.79E+07	1.18E+09	5.84E+08	5.85E+08	6.85E+08
March	3.79E+07	1.18E+09	6.35E+08	6.42E+08	8.06E+08
April	3.79E+07	1.18E+09	6.32E+08	6.38E+08	9.28E+08
May	3.79E+07	1.18E+09	6.31E+08	6.38E+08	9.28E+08
June	3.79E+07	1.18E+09	6.28E+08	6.34E+08	1.05E+09
July	3.79E+07	1.18E+09	6.27E+08	6.33E+08	1.05E+09
August	3.79E+07	1.18E+09	6.27E+08	6.33E+08	1.05E+09
September	3.79E+07	1.18E+09	6.27E+08	6.33E+08	9.28E+08
October	3.79E+07	1.18E+09	6.24E+08	6.30E+08	8.06E+08
November	3.79E+07	1.18E+09	6.23E+08	6.29E+08	7.36E+08
December	3.79E+07	1.18E+09	6.23E+08	6.29E+08	6.38E+08

Table B.5 Monthly, directly deposited fecal coliform loads in each reach of the Upper South Fork Catoctin Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
1	Human	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07
	Livestock	2.02E+09	2.50E+09	3.76E+09	5.01E+09	5.01E+09	6.26E+09
	Wildlife	8.51E+07	8.51E+07	8.51E+07	8.46E+07	8.46E+07	8.46E+07
2	Human	1.39E+08	1.39E+08	1.39E+08	1.39E+08	1.39E+08	1.39E+08
	Livestock	1.02E+09	1.26E+09	1.89E+09	2.52E+09	2.52E+09	3.15E+09
	Wildlife	4.96E+08	4.96E+08	4.96E+08	4.96E+08	4.96E+08	4.96E+08
3	Human	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08
	Livestock	3.30E+09	4.08E+09	6.11E+09	8.15E+09	8.15E+09	1.02E+10
	Wildlife	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09
4	Human	4.87E+08	4.87E+08	4.87E+08	4.87E+08	4.87E+08	4.87E+08
	Livestock	6.34E+09	7.84E+09	1.18E+10	1.57E+10	1.57E+10	1.96E+10
	Wildlife	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
1	Human	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07	1.88E+07
	Livestock	6.26E+09	6.26E+09	5.01E+09	3.76E+09	3.04E+09	2.02E+09
	Wildlife	8.42E+07	8.42E+07	8.42E+07	8.42E+07	8.42E+07	8.51E+07
2	Human	1.39E+08	1.39E+08	1.39E+08	1.39E+08	1.39E+08	1.39E+08
	Livestock	3.15E+09	3.15E+09	2.52E+09	1.89E+09	1.53E+09	1.02E+09
	Wildlife	4.96E+08	4.96E+08	4.96E+08	4.96E+08	4.96E+08	4.96E+08
3	Human	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08
	Livestock	1.02E+10	1.02E+10	8.15E+09	6.11E+09	4.95E+09	3.30E+09
	Wildlife	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09
4	Human	4.87E+08	4.87E+08	4.87E+08	4.87E+08	4.87E+08	4.87E+08
	Livestock	1.96E+10	1.96E+10	1.57E+10	1.18E+10	9.52E+09	6.34E+09
	Wildlife	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09

Table B.6 Monthly, directly deposited fecal coliform loads in each reach of the Lower South Fork Catoctin Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
5	Human	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08
	Livestock	4.57E+09	5.65E+09	8.47E+09	1.13E+10	1.13E+10	1.41E+10
	Wildlife	2.69E+09	2.69E+09	2.69E+09	2.69E+09	2.69E+09	2.69E+09
6	Human	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07
	Livestock	1.02E+09	1.26E+09	1.89E+09	2.52E+09	2.52E+09	3.15E+09
	Wildlife	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
5	Human	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08
	Livestock	1.41E+10	1.41E+10	1.13E+10	8.47E+09	6.86E+09	4.57E+09
	Wildlife	2.69E+09	2.69E+09	2.69E+09	2.69E+09	2.69E+09	2.69E+09
6	Human	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07
	Livestock	3.15E+09	3.15E+09	2.52E+09	1.89E+09	1.53E+09	1.02E+09
	Wildlife	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09

Table B.7 Monthly, directly deposited fecal coliform loads in each reach of the North Fork Catoctin Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
7	Human	1.02E+08	1.02E+08	1.02E+08	1.02E+08	1.02E+08	1.02E+08
	Livestock	1.15E+10	1.25E+10	2.16E+10	3.06E+10	3.06E+10	3.97E+10
	Wildlife	4.35E+08	4.35E+08	4.35E+08	4.34E+08	4.34E+08	4.34E+08
8	Human	8.91E+07	8.91E+07	8.91E+07	8.91E+07	8.91E+07	8.91E+07
	Livestock	3.55E+09	4.39E+09	6.58E+09	8.77E+09	8.77E+09	1.10E+10
	Wildlife	1.59E+09	1.59E+09	1.59E+09	1.59E+09	1.59E+09	1.59E+09
9	Human	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07
	Livestock	1.02E+09	1.26E+09	1.89E+09	2.52E+09	2.52E+09	3.15E+09
	Wildlife	1.44E+09	1.44E+09	1.44E+09	1.44E+09	1.44E+09	1.44E+09
10	Human	5.54E+07	5.54E+07	5.54E+07	5.54E+07	5.54E+07	5.54E+07
	Livestock	5.07E+09	6.27E+09	9.40E+09	1.25E+10	1.25E+10	1.57E+10
	Wildlife	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
7	Human	1.02E+08	1.02E+08	1.02E+08	1.02E+08	1.02E+08	1.02E+08
	Livestock	3.97E+10	3.97E+10	3.06E+10	2.16E+10	2.02E+10	1.15E+10
	Wildlife	4.32E+08	4.32E+08	4.32E+08	4.32E+08	4.32E+08	4.35E+08
8	Human	8.91E+07	8.91E+07	8.91E+07	8.91E+07	8.91E+07	8.91E+07
	Livestock	1.10E+10	1.10E+10	8.77E+09	6.58E+09	5.32E+09	3.55E+09
	Wildlife	1.59E+09	1.59E+09	1.59E+09	1.59E+09	1.59E+09	1.59E+09
9	Human	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07
	Livestock	3.15E+09	3.15E+09	2.52E+09	1.89E+09	1.53E+09	1.02E+09
	Wildlife	1.44E+09	1.44E+09	1.44E+09	1.44E+09	1.44E+09	1.44E+09
10	Human	5.54E+07	5.54E+07	5.54E+07	5.54E+07	5.54E+07	5.54E+07
	Livestock	1.57E+10	1.57E+10	1.25E+10	9.40E+09	7.61E+09	5.07E+09
	Wildlife	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09

Table B.8 Monthly, directly deposited fecal coliform loads in each reach of the Catoctin Creek impairment.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
11	Human	4.45E+07	4.45E+07	4.45E+07	4.45E+07	4.45E+07	4.45E+07
	Livestock	4.51E+09	5.60E+09	8.40E+09	1.12E+10	1.12E+10	1.40E+10
	Wildlife	2.61E+09	2.61E+09	2.61E+09	2.61E+09	2.61E+09	2.61E+09
12	Human	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08
	Livestock	5.07E+09	6.27E+09	9.40E+09	1.25E+10	1.25E+10	1.57E+10
	Wildlife	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.40E+09
13	Human	4.04E+07	4.04E+07	4.04E+07	4.04E+07	4.04E+07	4.04E+07
	Livestock	3.55E+09	4.39E+09	6.58E+09	8.77E+09	8.77E+09	1.10E+10
	Wildlife	1.72E+09	1.72E+09	1.72E+09	1.72E+09	1.72E+09	1.72E+09
14	Human	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08
	Livestock	4.05E+09	5.01E+09	7.51E+09	1.00E+10	1.00E+10	1.25E+10
	Wildlife	4.34E+09	4.34E+09	4.34E+09	4.34E+09	4.34E+09	4.34E+09
15	Human	2.04E+08	2.04E+08	2.04E+08	2.04E+08	2.04E+08	2.04E+08
	Livestock	3.95E+09	4.89E+09	7.33E+09	9.77E+09	9.77E+09	1.22E+10
	Wildlife	2.25E+09	2.25E+09	2.25E+09	2.25E+09	2.25E+09	2.25E+09
16	Human	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07
	Livestock	1.02E+09	1.26E+09	1.89E+09	2.52E+09	2.52E+09	3.15E+09
	Wildlife	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
11	Human	4.45E+07	4.45E+07	4.45E+07	4.45E+07	4.45E+07	4.45E+07
	Livestock	1.40E+10	1.40E+10	1.12E+10	8.40E+09	6.77E+09	4.51E+09
	Wildlife	2.61E+09	2.61E+09	2.61E+09	2.61E+09	2.61E+09	2.61E+09
12	Human	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08
	Livestock	1.57E+10	1.57E+10	1.25E+10	9.40E+09	7.61E+09	5.07E+09
	Wildlife	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.40E+09
13	Human	4.04E+07	4.04E+07	4.04E+07	4.04E+07	4.04E+07	4.04E+07
	Livestock	1.10E+10	1.10E+10	8.77E+09	6.58E+09	5.32E+09	3.55E+09
	Wildlife	1.72E+09	1.72E+09	1.72E+09	1.72E+09	1.72E+09	1.72E+09
14	Human	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08
	Livestock	1.25E+10	1.25E+10	1.00E+10	7.51E+09	6.07E+09	4.05E+09
	Wildlife	4.34E+09	4.34E+09	4.34E+09	4.34E+09	4.34E+09	4.34E+09
15	Human	2.04E+08	2.04E+08	2.04E+08	2.04E+08	2.04E+08	2.04E+08
	Livestock	1.22E+10	1.22E+10	9.77E+09	7.33E+09	5.93E+09	3.95E+09
	Wildlife	2.25E+09	2.25E+09	2.25E+09	2.25E+09	2.25E+09	2.25E+09
16	Human	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07
	Livestock	3.15E+09	3.15E+09	2.52E+09	1.89E+09	1.53E+09	1.02E+09
	Wildlife	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09

Table B.9 Existing annual loads from land-based sources for the Upper South Fork Catoctin Creek impairment.

Source	Woodland (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Residential (cfu/yr)	Cropland (cfu/yr)	Livestock Operations (cfu/yr)	Farmstead (cfu/yr)	Unimproved Pasture (cfu/yr)	Improved Pasture (cfu/yr)	Potential Livestock Access (cfu/yr)
<u>Pets</u>										
Dogs	0.00E+00	0.00E+00	0.00E+00	2.13E+14	0.00E+00	0.00E+00	1.59E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	6.35E+08	0.00E+00	0.00E+00	4.74E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	2.13E+14	0.00E+00	0.00E+00	1.59E+13	0.00E+00	0.00E+00	0.00E+00
<u>Human</u>										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	1.02E+12	0.00E+00	0.00E+00	1.29E+11	0.00E+00	0.00E+00	0.00E+00
<u>Livestock</u>										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+13	5.94E+14	3.19E+13
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.34E+12	3.54E+14	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.49E+14	3.38E+13	0.00E+00	0.00E+00	2.50E+13	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E+10	7.18E+11	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.49E+14	3.38E+13	0.00E+00	2.00E+13	9.74E+14	3.19E+13
<u>Wildlife</u>										
Raccoon	8.79E+13	0.00E+00	4.57E+12	1.17E+13	4.71E+13	4.70E+11	1.82E+12	4.85E+12	1.78E+14	1.06E+13
Muskrat	2.76E+13	0.00E+00	4.64E+11	9.58E+11	4.44E+12	0.00E+00	0.00E+00	3.51E+12	3.50E+13	1.44E+13
Deer	8.55E+12	0.00E+00	0.00E+00	3.02E+10	3.38E+12	0.00E+00	0.00E+00	2.35E+10	2.59E+12	4.81E+10
Turkey	6.44E+09	0.00E+00	0.00E+00	0.00E+00	2.75E+08	0.00E+00	0.00E+00	4.71E+06	9.27E+08	2.16E+06
Goose	1.71E+10	0.00E+00	3.38E+08	9.37E+08	4.69E+09	3.41E+08	3.44E+08	1.74E+09	3.65E+10	8.19E+09
Duck	1.56E+08	0.00E+00	3.07E+06	8.52E+06	4.27E+07	3.10E+06	3.13E+06	1.58E+07	3.32E+08	7.45E+07
Unquantifiable	1.34E+13	0.00E+00	5.25E+11	1.32E+12	5.71E+12	4.78E+10	1.85E+11	9.55E+11	2.29E+13	3.00E+12
Total	1.37E+14	0.00E+00	5.56E+12	1.40E+13	6.06E+13	5.18E+11	2.00E+12	9.35E+12	2.39E+14	2.81E+13

Table B.10 Existing annual loads from land-based sources for the Lower South Fork Catoctin Creek impairment.

Source	Woodland (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Residential (cfu/yr)	Cropland (cfu/yr)	Livestock Operations (cfu/yr)	Farmstead (cfu/yr)	Unimproved Pasture (cfu/yr)	Improved Pasture (cfu/yr)	Potential Livestock Access (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	6.13E+13	0.00E+00	0.00E+00	1.00E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	1.83E+08	0.00E+00	0.00E+00	3.00E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	6.13E+13	0.00E+00	0.00E+00	1.00E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	5.28E+11	0.00E+00	0.00E+00	1.21E+11	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.66E+12	2.60E+14	1.41E+13
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.74E+12	3.57E+14	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E+11	4.14E+12	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.78E+09	3.59E+11	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E+13	6.21E+14	1.41E+13
Wildlife										
Raccoon	4.16E+13	0.00E+00	1.01E+12	2.64E+12	3.97E+12	0.00E+00	8.90E+11	3.98E+12	1.16E+14	6.64E+12
Muskrat	2.05E+13	0.00E+00	1.88E+11	9.87E+09	9.87E+10	0.00E+00	0.00E+00	4.16E+12	2.53E+13	1.35E+13
Deer	4.08E+12	0.00E+00	0.00E+00	6.41E+09	3.84E+11	0.00E+00	0.00E+00	1.90E+10	1.62E+12	2.97E+10
Turkey	3.04E+09	0.00E+00	0.00E+00	0.00E+00	3.12E+07	0.00E+00	0.00E+00	3.71E+06	5.80E+08	1.24E+06
Goose	1.03E+10	0.00E+00	6.05E+07	1.12E+08	2.42E+08	0.00E+00	1.08E+08	1.67E+09	2.03E+10	5.66E+09
Duck	9.40E+07	0.00E+00	5.51E+05	1.01E+06	2.20E+06	0.00E+00	9.85E+05	1.52E+07	1.85E+08	5.14E+07
Unquantifiable	7.40E+12	0.00E+00	1.27E+11	2.70E+11	4.55E+11	0.00E+00	9.04E+10	9.49E+11	1.52E+13	2.48E+12
Total	7.36E+13	0.00E+00	1.32E+12	2.93E+12	4.91E+12	0.00E+00	9.80E+11	9.10E+12	1.58E+14	2.27E+13

Table B.11 Existing annual loads from land-based sources for the North Fork Catoctin Creek impairment.

Source	Woodland (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Residential (cfu/yr)	Cropland (cfu/yr)	Livestock Operations (cfu/yr)	Farmstead (cfu/yr)	Unimproved Pasture (cfu/yr)	Improved Pasture (cfu/yr)	Potential Livestock Access (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	6.62E+13	0.00E+00	0.00E+00	9.22E+12	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	1.98E+08	0.00E+00	0.00E+00	2.75E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	6.62E+13	0.00E+00	0.00E+00	9.22E+12	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	3.05E+11	0.00E+00	0.00E+00	5.44E+10	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.94E+14	0.00E+00	0.00E+00	1.41E+12	2.82E+14	2.08E+13
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E+13	6.40E+14	3.45E+13
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.33E+12	5.37E+14	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.30E+10	2.17E+12	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.94E+14	0.00E+00	0.00E+00	2.45E+13	1.46E+15	5.53E+13
Wildlife										
Raccoon	1.22E+14	0.00E+00	3.10E+10	1.92E+12	2.09E+13	0.00E+00	8.14E+11	2.74E+12	1.62E+14	7.65E+12
Muskrat	5.76E+13	0.00E+00	0.00E+00	2.47E+11	1.53E+12	0.00E+00	0.00E+00	4.47E+12	3.79E+13	1.76E+13
Deer	1.52E+13	0.00E+00	0.00E+00	3.17E+09	1.46E+12	0.00E+00	0.00E+00	1.73E+10	2.60E+12	3.45E+10
Turkey	1.15E+10	0.00E+00	0.00E+00	0.00E+00	1.19E+08	0.00E+00	0.00E+00	2.84E+06	9.30E+08	1.85E+06
Goose	2.80E+10	0.00E+00	0.00E+00	4.53E+08	1.85E+09	0.00E+00	1.75E+08	2.27E+09	3.47E+10	8.03E+09
Duck	2.54E+08	0.00E+00	0.00E+00	4.12E+06	1.68E+07	0.00E+00	1.59E+06	2.06E+07	3.15E+08	7.30E+07
Unquantifiable	2.14E+13	0.00E+00	3.15E+09	2.28E+11	2.47E+12	0.00E+00	8.28E+10	8.64E+11	2.17E+13	3.08E+12
Total	2.16E+14	0.00E+00	3.42E+10	2.40E+12	2.64E+13	0.00E+00	8.97E+11	8.09E+12	2.24E+14	2.83E+13

Table B.12 Existing annual loads from land-based sources for the Catoctin Creek impairment.

Source	Woodland (cfu/yr)	Water (cfu/yr)	Commercial Services (cfu/yr)	Residential (cfu/yr)	Cropland (cfu/yr)	Livestock Operations (cfu/yr)	Farmstead (cfu/yr)	Unimproved Pasture (cfu/yr)	Improved Pasture (cfu/yr)	Potential Livestock Access (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	0.00E+00	1.75E+14	0.00E+00	0.00E+00	2.16E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	5.24E+08	0.00E+00	0.00E+00	6.44E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	1.75E+14	0.00E+00	0.00E+00	2.16E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	0.00E+00	1.34E+12	0.00E+00	0.00E+00	1.96E+11	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.89E+13	1.03E+15	5.58E+13
Horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.53E+13	1.19E+15	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.01E+11	1.02E+13	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.54E+11	1.33E+13	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.49E+13	2.25E+15	5.58E+13
Wildlife										
Raccoon	1.93E+14	0.00E+00	1.11E+11	5.87E+12	3.63E+13	9.92E+09	1.48E+12	1.06E+13	3.32E+14	1.86E+13
Muskrat	1.90E+14	0.00E+00	1.17E+11	1.10E+12	6.98E+12	0.00E+00	1.68E+11	5.41E+12	8.15E+13	3.55E+13
Deer	1.74E+13	0.00E+00	0.00E+00	1.10E+10	2.58E+12	0.00E+00	0.00E+00	6.13E+10	4.69E+12	8.69E+10
Turkey	1.30E+10	0.00E+00	0.00E+00	0.00E+00	2.09E+08	0.00E+00	0.00E+00	1.03E+07	1.68E+09	4.40E+06
Goose	8.13E+10	0.00E+00	3.82E+07	1.21E+09	3.23E+09	0.00E+00	3.51E+08	3.64E+09	6.62E+10	1.54E+10
Duck	7.39E+08	0.00E+00	3.48E+05	1.10E+07	2.94E+07	0.00E+00	3.19E+06	3.31E+07	6.02E+08	1.40E+08
Unquantifiable	4.66E+13	0.00E+00	2.68E+10	7.41E+11	4.87E+12	1.01E+09	1.72E+11	1.80E+12	4.49E+13	6.54E+12
Total	4.47E+14	0.00E+00	2.55E+11	7.72E+12	5.07E+13	1.09E+10	1.82E+12	1.79E+13	4.63E+14	6.07E+13

Table B.13 Existing annual loads from direct-deposition sources for the Upper South Fork Catoctin Creek impairment.

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	2.74E+11
Lateral Flow	1.23E+09
Total	2.75E+11
Livestock	
Dairy	0.00E+00
Beef	9.71E+12
Swine	0.00E+00
Horse	0.00E+00
Total	9.71E+12
Wildlife	
Raccoon	2.90E+11
Muskrat	1.45E+12
Deer	4.33E+09
Turkey	7.33E+05
Goose	7.00E+08
Duck	9.57E+06
Unquantifiable	1.74E+11
Total	1.92E+12

Table B.14 Existing annual loads from direct-deposition sources for the Lower South Fork Catoctin Creek impairment.

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	9.52E+10
Lateral Flow	3.82E+08
Total	9.56E+10
Livestock	
Dairy	0.00E+00
Beef	4.28E+12
Swine	0.00E+00
Horse	0.00E+00
Total	4.28E+12
Wildlife	
Raccoon	1.47E+11
Muskrat	1.10E+12
Deer	1.79E+09
Turkey	3.53E+05
Goose	3.77E+08
Duck	5.17E+06
Unquantifiable	1.26E+11
Total	1.38E+12

Table B.15 Existing annual loads from direct-deposition sources for the North Fork Catoctin Creek impairment.

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	1.12E+11
Lateral Flow	5.17E+08
Total	1.13E+11
Livestock	
Dairy	6.33E+12
Beef	1.05E+13
Swine	0.00E+00
Horse	0.00E+00
Total	1.68E+13
Wildlife	
Raccoon	2.65E+11
Muskrat	2.00E+12
Deer	5.73E+09
Turkey	1.21E+06
Goose	7.57E+08
Duck	1.04E+07
Unquantifiable	2.27E+11
Total	2.50E+12

Table B.16 Existing annual loads from direct-deposition sources for the Catoctin Creek impairment.

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	2.25E+11
Lateral Flow	1.74E+09
Total	2.27E+11
Livestock	
Dairy	0.00E+00
Beef	1.70E+13
Swine	0.00E+00
Horse	0.00E+00
Total	1.70E+13
Wildlife	
Raccoon	5.00E+11
Muskrat	5.54E+12
Deer	7.30E+09
Turkey	1.44E+06
Goose	1.71E+09
Duck	2.34E+07
Unquantifiable	6.03E+11
Total	6.65E+12

APPENDIX C

QUESTIONS ASKED IN PUBLIC MEETING

February 26, 2002 – **DRAFT MEMORANDUM**

TO: Catoctin Creek TMDL Development Participants

FROM: Kate Bennett, Virginia DEQ, Northern Virginia Regional Office

SUBJECT: Minutes for 1/23/2002 Public Meeting

The purpose of this memo is to provide the minutes for the second public meeting held for developing the Catoctin Creek Fecal Coliform Total Maximum Daily Load (TMDL). The meeting was held at the Old Stone Schoolhouse in Hillsboro, Virginia on January 23, 2002. The meeting began at 7:00 p.m. A list of those in attendance is included as Attachment A to this memorandum.

Linda Erbs, Chief Engineer with the Loudoun County Department of Building and Development, facilitated the meeting by providing background on the project and introducing the representatives speaking at the meeting.

Charles Martin of the Virginia Department of Environmental Quality (DEQ) discussed fecal coliform TMDLs in general and presented the Consent Decree schedule that is driving the development of TMDLs in Virginia. Mr. Martin also discussed the fecal coliform bacteria water quality standards and summarized the data used to identify Catoctin Creek as impaired. Finally, Mr. Martin discussed the public participation and implementation components of TMDL development.

Charles Lunsford of the Virginia Department of Conservation and Recreation (DCR) provided background on nonpoint source (NPS) TMDLs in Virginia and on the Memorandum of Agreement between DCR and DEQ. Mr. Lunsford also provided a list of TMDLs approved to date in Virginia, and described implementation plan development.

Phillip McClellan of MapTech, Inc. discussed the development of the Catoctin Creek fecal coliform TMDL and presented information on the fecal coliform source inventory and modeling hydrology. Land use in the watershed is predominantly agricultural and forested, with only small areas of urban or developing land. The model was calibrated for the period from October 1990 through September 1995, and validated for October 1995 through September 1999. The closest precipitation stations with 15-minute interval data are located in neighboring Maryland and West Virginia. Someone suggested checking with the wastewater treatment plants (WWTPs) in the watershed for local precipitation records. Large WWTPs will collect daily rainfall data in order to predict flow volumes. The 15-minute interval data could then be used to distribute the daily data so that the more accurate local data could be used in the model.

The sources of fecal coliform bacteria in the Catoctin watershed are livestock, wildlife, pets, and humans (wastewater treatment plants, failing septic systems and biosolids applications). Populations of beef cattle, horses and sheep in the watershed were estimated based on state agricultural statistics, conversations with the local Soil and Water Conservation District, and watershed observations. The number of dairy cattle in the watershed is still unclear. Wildlife populations were estimated based on habitat descriptions and population densities provided by the Department of Game and Inland Fisheries (DGIF).

The human population in the Catoctin watershed is estimated to have grown at an annual rate of 9.69% from 1990 to 2000. The total population in the watershed is estimated at 5,970, with approximately 33 septic systems located within 50 feet of a stream. Based on repair permits, the failure rate of septic systems in the watershed is estimated as 0.33% to 0.62%. Straight pipes are estimated to occur at a rate of 0.08% to 0.33%. There are six VPDES permits in the watershed and biosolids have been applied to parts of the watershed. Initial bacterial source tracking (BST) results suggest that livestock is the dominant source of fecal coliform bacteria in Catoctin Creek, North Fork Catoctin Creek, and Lower South Fork Catoctin Creek. Human sources are dominant in the Upper South Fork Catoctin Creek. Any input from residents on the accuracy of this finding would be appreciated.

Copies of hand-out materials provided at the meeting are included as Attachment B to this memorandum. Included in Attachment B are the meeting agenda, the Catoctin Creek TMDL Fact Sheet, a map of the Catoctin Creek watershed, and the slide presentation hand-outs for DEQ, DCR, and MapTech. Larry Yates with the Loudoun County Division of Environmental Health was present at the meeting and provided information regarding funding available to help homeowners defray the costs of septic system repairs. This information is included in Appendix C.

Many questions were asked during the course of the meeting. The following presents a record of the questions raised and responses provided. Note that this record paraphrases the questions and responses, and is not necessarily presented in the same order as the questions were asked.

<u>Question 1</u>: Does the TMDL process address groundwater? Surface water? Drinking water?

Response: TMDLs are only developed for surface waters.

<u>Question 2</u>: Is monitoring conducted at several points along the stream?

Response: The number of monitoring locations depends on the variability of the stream. Monitoring on Catoctin Creek will be described in more detail later in the presentation.

<u>Question 3</u>: What does impaired mean?

Response: Impaired means polluted.

Question 4: What do you mean by implementation? Do you mean disturbing vegetation?

Response: The first step is to identify the sources of fecal coliform bacteria to the stream. The second step is to develop and implementation plan to reduce these sources. This is done primarily through best management practices (BMPs). We are currently still working on the first step.

Question 5: A large farm in the headwaters of the North Fork Catoctin Creek is being developed with over 100 houses going in. Will these new houses be required to hook up to the sanitary sewer system, instead of using septic systems?

Response: The TMDL won't control local land use decisions. The MapTech presentation will discuss sources in more detail. Once the TMDL has been developed, the implementation process will begin and will include opportunities for public participation.

Question 6: So between the TMDL development and implementation phases, additional pollution sources can be added to the watershed?

Response: Yes.

Question 7: What will be done about wildlife sources?

Response: Where wildlife is found to be the dominant source causing the impairment, a use attainability analysis (UAA) can be done to describe factors limiting the designated use of the waterbody. Where the UAA indicates that the designated use cannot be attained, a change can be made, for instance from primary contact recreation to secondary contact recreation.

Question 8: How does the impairment in Catoctin Creek compare to other streams in the state?

Response: Impairments in the Blackwater and Shenandoah Rivers are more severe.

Question 9: Are the watershed data management (WDM) and user control input (UCI) files for the model available for review?

Response: The WDMs and UCIs are still in draft form.

Question 10: Is a detailed map of the watershed available in order to provide feedback?

Response: We can make a map available. Contact Kate Bennett.

Question 11: What have the implementation plans for other TMDLs looked like?

Response: The implementation plans done to date have been for highly agricultural areas. Some have relied solely on reductions of fecal coliform bacteria from livestock. All have required a reduction of direct deposition of livestock waste to the streams (streambank fencing).

Question 12: What can be done about failing septic systems?

Response: There is money available to correct failing septic systems. Septic systems have a finite lifespan of 25 to 40 years, but can last longer if maintained correctly. Septic systems should be pumped out every 3 to 5 years to prevent health hazards and to prolong the life of the system.

Question 13: Is there any regulation regarding how often septic systems should be pumped out?

Response: Currently there is no such regulation, but it is anticipated in the next year or so.

APPENDIX D

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY TMDL REVIEW AND SUBSEQUENT RESPONSE TO REVIEW

Response to USEPA "Comments on the Fecal Coliform Total Maximum Daily Load (TMDLs) for Catoctin Creek"

Note: USEPA comments are in italicized text followed by response.

1.) *How many segments of the Catoctin were listed on the 1998 Section 303(d) list?*

The following three (3) segments were listed on the 1998 Section 303(d) list: Catoctin Creek, North Fork Catoctin Creek, and South Fork Catoctin Creek. The South Fork Catoctin Creek impairment will be extended from the 6.01 to 17.26 river mile on the 2002 Section 303(d) list. Being proactive, the Virginia Department of Conservation and Recreation and the Virginia Department of Environmental Quality decided to calculate a TMDL for the extended segment. In the TMDL report, the South Fork Catoctin Creek was broken into two segments. The Lower South Fork Catoctin Creek was the segment listed in the 1998 Section 303(d) list and the Upper South Fork Catoctin Creek is the segment that will be listed on the 2002 Section 303(d) list. The Upper South Fork Catoctin Creek impairment begins approximately 1.10 river miles upstream from the Route 761/Route 719 intersection, downstream to its confluence with the Lower South Fork Catoctin Creek. The Lower South Fork Catoctin Creek impaired segment begins approximately 0.55 river miles upstream from the Route 9 bridge downstream to its confluence with Catoctin Creek.

2.) *The United States Environmental Protection Agency believes that the wildlife load is being over represented by adding an additional 10% of the wildlife load to all land uses. This additional loading should be removed from future TMDLs.*

As all warm-blooded mammals produce fecal coliform in their intestines, the wildlife fecal coliform load estimate consisted of identifying the load associated with the predominant wildlife species in the watershed as well as a representative load from the remaining species (e.g. birds, squirrels, chipmunks, etc.). The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), citizens from the watershed, source sampling, and site visits. Population densities for these animals were based on studies conducted by the VDGIF (report Table 3.8). Similar studies quantifying the population density and associated loads from various other species known to inhabit the watershed are limited. Liecsko et. al., 1993 reported an average fecal coliform concentration from roof downspout samples of 59 MPN/100ml. Previously reported typical concentrations of fecal coliform counts from rooftops of 100 MPN/100 ml by Ontario Ministry of the Environment, 1983 was also cited by Liecsko et. al., 1993. Based on this study, it was estimated that birds and smaller animals (e.g. squirrels) were afforded rooftop access and therefore contributed the resulting FC load. Recognition was made that a comparable load could be expected in the Catoctin Creek watershed knowing these species exist in the watershed and therefore should not equal zero. In order to account for these potential loads, an explicit un-quantifiable load of 10% of the load from quantifiable species was used in the Catoctin Creek watershed. Future evaluation of the un-quantifiable load is certainly available for interpretation by VADCR, VADEQ, and USEPA.

3.) Please make sure that the North and South for of the Catoctin are referred to as the North and South Fork of the Catoctin.

Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report contains notation corrections as noted in this comment.

4.) Page 1-9, Please change the last sentence on this page to state "This is obviously an impractical action. Clearly the reduction of wildlife or changing of a natural background condition is not the intended goal of a TMDL."

The following sentences were changed in Section 1.3.3 Wildlife Contribution in Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report.

FROM:
"This is obviously an impractical action. Clearly, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL or any other federal and state water quality management programs."

TO:
"This is obviously an impractical action. While managing over-populations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL."

5.) Page 2-4, Is it possible to document the land uses and stream access areas around the more extensively sampled monitoring locations?

GIS analysis can be performed to calculate land use area around a given point after defining the distance required away from that point. Each impairment was divided into subwatersheds for modeling purposes. To go beyond this level of spatial resolution for describing the land use was not deemed necessary for this effort. Figure 1 illustrates the subwatershed delineation used to represent the Catoctin Creek watershed and the location of the VADEQ ambient water quality stations. Tables 1-4 list the land use acreage within each subwatershed.

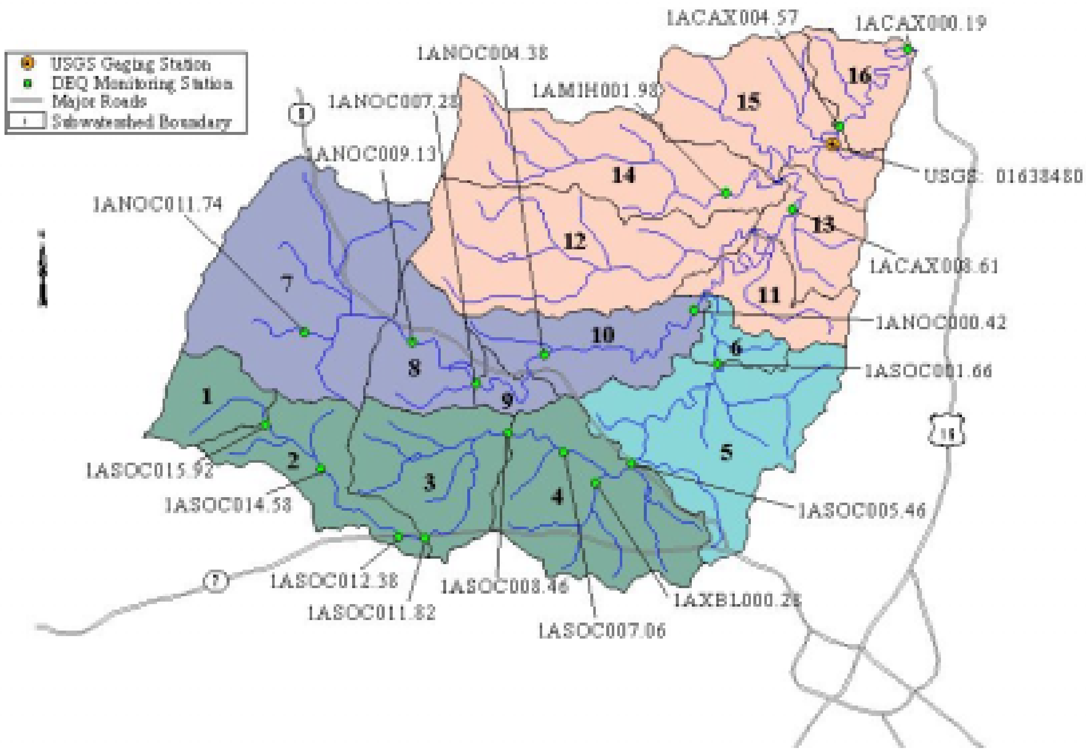

Figure 1. Subwatersheds delineated for modeling, location of VADEQ water quality monitoring stations, and USGS gaging station in the Catoctin Creek watershed.

Table 1. Land use acreage per subwatershed for Upper South Fork Catoctin Creek impairment.

Land use	Subw'shed 1 Acreage	Subw'shed 2 Acreage	Subw'shed 3 Acreage	Subw'shed 4 Acreage
Woodland	977.1	900.4	713.7	841.2
Water	4.7	18.4	38.3	38.7
Commercial & Services	0.0	56.9	55.0	87.8
Residential	8.4	69.2	68.2	326.8
Cropland	87.2	236.8	1213.6	623.6
Livestock Operations	0.0	0.0	0.0	11.4
Farmstead	5.3	8.7	23.0	37.6
Unimproved Pasture	1.5	33.1	34.9	85.1
Improved Pasture	605.5	1573.8	1640.5	3478.6
Potential Livestock Access	13.3	27.9	64.6	106.9

Table 2. Land use acreage per subwatershed for Lower South Fork Catoctin Creek impairment.

Land use	Subw'shed 5 Acreage	Subw'shed 6 Acreage
Woodland	1518.6	120.0
Water	33.7	14.7
Commercial & Services	35.2	1.8
Residential	123.2	6.0
Cropland	148.3	97.4
Livestock Operations	0.0	0.0
Farmstead	28.8	3.3
Unimproved Pasture	125.2	0.0
Improved Pasture	3968.2	596.1
Potential Livestock Access	112.5	19.8

Table 3. Land use acreage per subwatershed for North Fork Catoctin Creek impairment.

Land use	Subw'shed 7 Acreage	Subw'shed 8 Acreage	Subw'shed 9 Acreage	Subw'shed 10 Acreage
Woodland	4096.1	995.5	98.6	911.9
Water	24.6	38.5	3.5	47.3
Commercial & Services	0.0	2.5	0.0	0.0
Residential	34.9	18.7	5.4	24.3
Cropland	242.1	288.9	114.8	288.0
Livestock Operations	0.0	0.0	0.0	0.0
Farmstead	18.3	9.7	3.2	5.5
Unimproved Pasture	19.3	50.1	6.7	37.9
Improved Pasture	3801.2	1091.4	397.3	2027.6
Potential Livestock Access	82.5	23.6	17.2	29.0

Table 4. Land use acreage per subwatershed for Catoctin Creek impairment.

Land use	Subw'shed 11 Acreage	Subw'shed 12 Acreage	Subw'shed 13 Acreage	Subw'shed 14 Acreage	Subw'shed 15 Acreage	Subw'shed 16 Acreage
Woodland	743.3	1661.8	653.4	1785.4	1264.0	873.0
Water	38.6	73.5	19.5	28.4	41.6	46.1
Commercial & Services	0.0	0.0	0.6	1.2	3.6	0.6
Residential	11.8	65.2	9.0	75.7	71.9	13.2
Cropland	124.1	556.0	47.1	456.0	322.6	139.9
Livestock Operations	0.0	0.8	0.0	0.0	0.0	0.0
Farmstead	1.7	18.0	5.5	13.9	12.2	3.5
Unimproved Pasture	40.9	102.5	0.0	76.4	75.0	108.4
Improved Pasture	1187.9	4434.6	1117.7	2974.5	2785.5	708.4
Potential Livestock Access	31.4	118.2	35.1	83.8	81.8	19.9

6.) Page 2-6, How was the Bacterial Source Tracking data analyzed, was the data analyzed as either belonging to wildlife, livestock, or human or were there other subcategories? Is it possible that there is overlap between the wildlife and livestock categories?

The correct classification rate (i.e. the percentage of known isolates correctly classified) for the Catoctin Creek study was 84%. This indicates a high degree of correct classification with only 16% of isolates being misclassified. Isolates that were misclassified included wildlife isolates incorrectly classified as originating from livestock as well as livestock isolates incorrectly classified as originating from wildlife.

7.) Page 2-13, Why is the highest mean fecal coliform concentration occurring in December?

Statistical analysis was utilized to determine long-term trends in the fecal coliform concentration data collected by the VADEQ. A Seasonal Kendall Test was used to examine long-term trends by ignoring seasonal cycles, which improves the chances of finding existing trends in data that are likely to have seasonal patterns. In addition, the Moods Median Test was used to test whether significant differences in median fecal coliform concentrations existed between months within years. While the average fecal coliform concentration reported in December may be the greatest, results from the Moods Median Test indicated no significant difference in monthly fecal coliform concentrations within years. Speculation on reasons that the average fecal coliform concentration was greatest in December is difficult given that concentrations in December are not statistically greater than the other months.

8.) Page 3-7, Please remove the word "and" in the following sentence "The average amount of time spent by dairy and beef cattle in close proximity to streams for each month is given in Tables 3.5, through, ~~and Table~~ 3.7."

Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report contains correction as noted in this comment.

9.) Page 3-8, Please mention that the fecal coliform concentrations for biosolids from the waste water treatment plants was obtained through sampling.

The sentence was amended in Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report:

FROM:
"Average fecal coliform densities measured were 879 cfu/g (VADCR, 2002)."

TO:
"Average fecal coliform densities measured from samples collected at Blue Plains WWWTP were 879 cfu/g (VADCR, 2002)."

10.) Page 4-8, How was the 0.205% rate for uncontrolled dischargers determined?

The straight pipe estimation was based on data received from VDH for Loudoun County (i.e. 25 straight pipes). The countywide number was used to form a ratio of the number of straight pipes per the number of private residential sewage treatment systems. This ratio was applied to the Catoctin Creek watershed to formulate the numbers in report Table 4.4.

11.) Page 4-18, Please note values that are outside of the typical range.

Table 5 lists the parameter values that are outside of the typical range of parameter values.

Table 5. Calibrated model parameters outside of typical range of values.

Parameter	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
LSUR	100 – 700	32 – 1467	32 –1467
NSUR	0.10 – 0.50	0.1 – 0.4	0.048 – 0.576
LZETP	0.1 – 0.9	0.5 – 0.8	0.189 – 0.960

The LSUR parameter was not used as a calibration parameter. Parameter values were derived using a detailed drainage network provided by the Loudoun County GIS Division. This level of detail provided considerably more confidence in the estimates compared to typical values derived from coarser GIS data layers (i.e. BASINS). For NSUR and LZETP, the typical parameter ranges represent calibrated values previously used in other watersheds. The range serves as a guideline for parameter values and is not a model constraint. During model calibration, parameters are adjusted until an acceptable correspondence between measured and simulated data for that particular watershed is achieved resulting in some parameters being slightly outside of the range of values specific to other watersheds.

12.) Page 4-33, It appears as though the observed data is outside the modeled maximums and minimums, please explain.

The maximum and minimum modeled concentrations depicted were determined from a 48-hour window centered on a single observed value. These plots were developed to respond to errors associated with temporal shifts in the modeling (e.g. where the hydrology calibration lags or leads the observed hydrographs). With an ideal fit, the observed data would be bound by the maximum and minimum modeled values. There were exceptions to this ideal case. Some observations fell outside these limits. These were attributed to the censuring of data, natural variability in sample analysis (e.g. significant variability in analysis of field duplicate samples), unknown spatial variability in rainfall distribution, and modeling uncertainty. However, generally, the observed values were bound by the limits.

13.) Page 4-51, What were the hydrologic and loading conditions associated with the summer of 1996?

The assumption was made that the referenced page number was referring to data denoted in report Figure 4.30. Specifically, rationale was needed to explain why the geometric mean in summer months of 1996 was less than summer months in other years represented.

Hydrologic conditions for 1996 can be viewed in report Figure 4.6. For comparison, hydrologic conditions for 1993-1995 are contained in report Figure 4.4 and hydrologic conditions for 1997 are outlined in report Figure 4.6. From report Figure 4.6, flows during the summer months in 1996 were considerably higher than the other modeled summer months depicted in report Figure 4.30.

Model loadings in HSPF are set-up on a yearly basis so that each year in a simulation period has the same loadings. Tables in Appendix B summarize land-applied and direct loadings for existing conditions on a monthly basis for a given year. Keeping in mind that report Figure 4.30 shows the geometric mean for existing conditions in the Upper South Fork Catoctin Creek, the summer months with low flow resulted in a higher geometric mean, whereas the higher flows in 1996 reduced the geometric mean.

14.) Page 5-11, Is the 100% increase in direct deposit loading scenario correct in figure 5.7?

Yes, the line depicting the percent difference in geometric mean when direct loads are increased by 100% is correct.

15.) *Page 5-12, Does the Purcellville Water Treatment Plant contribute fecal coliform to the Catoctin? If not please remove the statement "... Contributes negligible amounts of fecal coliform."*

The Purcellville Water Treatment Plant was modeled as contributing zero fecal coliform to the Upper South Fork Catoctin Creek. The referenced statement was removed from the sentence in Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report. In addition, updated information received from VADEQ specified that the general permit for a residential sewage treatment plant in North Fork Catoctin Creek watershed had expired, and correspondence with the permit holder indicated that while the permit was obtained, the system was never installed. As a result, no allocation was specified for this private residence. Section 5.3.1 Wasteload Allocations was updated as follows:

FROM:
"There are four point sources currently permitted to discharge in the Catoctin Creek Watershed (Figure 3.1 and Table 3.1). Two of these sources (i.e. Town of Purcellville WTP, and Town of Hamilton STP) discharge in the Upper South Fork drainage. The discharge from the Purcellville Water Treatment Plant is not permitted for fecal coliform control and contributes negligible amounts of fecal coliform. For allocation runs, the plant was modeled as discharging the average recorded value of water, with no fecal coliform. The allocation for this point source is zero cfu/100 ml. The allocation for the Hamilton Sewage Treatment Plant is equivalent to its current permit levels (0.16 MGD and 200 cfu/100 ml).

There is one permitted discharge in the North Fork Catoctin drainage, which comes from a private residential sewage treatment system. The allocation for this private residence is equivalent to its current permit levels (0.001 MGD and 200 cfu/100 ml). The remaining permitted discharge, the Waterford Sewage Treatment Plant, drains to the Lower South Fork of Catoctin Creek. The allocation for this point is also equivalent to its current permit levels (0.058 MGD and 200 cfu/100 ml)."

TO:
"There are four point sources currently permitted to discharge in the Catoctin Creek watershed (Figure 3.1 and Table 3.1). Two of these sources (i.e. Town of Purcellville WTP, and Town of Hamilton STP) discharge in the Upper South Fork Catoctin Creek drainage. The discharge from the Purcellville Water Treatment Plant is not permitted for fecal coliform control. For allocation runs, the plant was modeled as discharging the average recorded value of water, with no fecal coliform. The allocation for this point source is zero cfu/100 ml. The allocation for the Hamilton Sewage Treatment Plant is equivalent to its current permit levels (0.16 MGD and 200 cfu/100 ml).

There was one permitted discharge in the North Fork Catoctin Creek drainage, which comes from a private residential sewage treatment system. According to VADEQ, the general permit for the residential sewage treatment plant has expired, and correspondence with the permit holder indicated that while the permit was obtained, the system was never installed. As a result, no allocation was specified for this private residence. The remaining permitted discharge, the Waterford Sewage Treatment Plant, drains to the Lower South Fork Catoctin Creek. The allocation for this point is also equivalent to its current permit levels (0.058 MGD and 200 cfu/100 ml)."

16.) Section 5.0, The load and waste load allocations appear to be identical to the loads and waste load allocations associated with Willis River is this correct? The percent reductions documented in the text and tables do not correlate.

Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report contains numbers associated with The Catoctin Creek TMDL.

17.) Appendices B and C were not included with the draft.

Version 29 of the Fecal Coliform TMDL (Total Maximum Daily Load) Development for the Catoctin Creek Impairments, Virginia report contains Appendices B and C.

18. a) How was the Margin of Safety (MOS) determined?

The MOS was predetermined based on protocol established by USEPA Region 3 during the Fecal Coliform TMDL Development for Muddy Creek, Virginia study. The VADCR and VADEQ have continued to utilize this approach for over 30 fecal coliform TMDLs submitted to USEPA Region 3.

b) Is this based on a further reduction of direct deposit sources?

No, an explicit MOS of 5% of the maximum 30-day geometric mean standard was utilized.

c) Will there be a land based load reduction associated with the buffer strips associated with cattle removal devices? If there is an expected land based load reduction can it be quantified?

We expect to observe some reductions of land-based FC delivered to the stream as a result of livestock exclusion. The reductions are expected to result from increased infiltration and thereby degradation of FC in buffered areas. These reductions are dependent on the quantity, quality, and efficiency of the buffers installed.

GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration****.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Deterministic model. *A model that does not include built-in variability: same input will always result in the same output.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Empirical model. *Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

First-order kinetics. *The type of relationship describing a dynamic reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Hyetograph. *Graph of rainfall rate versus time during a storm event.*

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. *Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25^{th}, 50^{th}, and 75^{th} percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50^{th} quartile is also known as the median. The 25^{th} and 75^{th} quartiles are referred to as the lower and upper quartiles, respectively.

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reserve capacity. *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient. *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles.

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation. *The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 ml geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based effluent limitations (WQBEL). *Effluent limitations applied to dischargers when technology-based limitations alone would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.*

Water quality-based permit. *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

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